VEGETATION OF THE DEVONIAN PERIOD—
RESTORED.

ACADIAN GEOLOGY.

THE

GEOLOGICAL STRUCTURE,

ORGANIC REMAINS, AND MINERAL RESOURCES

OF

NOVA SCOTIA, NEW BRUNSWICK, AND PRINCE EDWARD ISLAND.

BY

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WITH A GEOLOGICAL MAP AND NUMEROUS ILLUSTRATIONS.

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TO

SIR CHARLES LYELL, BART., M.A., F.R.S., ETC.

MY DEAR SIR,

After an interval of twelve years, it affords me much pleasure to renew the dedication of this work to you; and in doing so to repeat my grateful acknowledgments, for the kind aid and encouragement extended to me as a young geologist, and for the friendly interest which you have ever manifested in the labours of my riper years.

I am,

With sincere gratitude and respect,

Yours faithfully,

J. W. DAWSON.

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PREFACE TO THE SECOND EDITION.

In the Preface to the First Edition of this Work, its intention was stated to be—to place within the reach of the people of the districts to which it relates, a popular account of the more recent discoveries in the Geology and mineral resources of their country, and at the same time to give to geologists in other countries a connected view of the structure of a very interesting portion of the American continent, in its relation to general and theoretical Geology. In the Edition now issued, it is hoped still more completely to fulfil this design, with reference to the present more advanced condition of knowledge.

With regard to the purely local Geology, the author has endeavoured to convey a knowledge of the structure and fossils of the region in such a manner as to be intelligible to ordinary readers, and has devoted much attention to all questions relating to the nature and present or prospective value of deposits of useful minerals. It is proper to add that, as he has no pecuniary interest in the mines of the Acadian provinces, and has received no public aid in furtherance of his explorations, he has had no inducement to write otherwise than impartially; and where he may appear to give undue prominence to one district in comparison with another, this is merely because his descriptions are necessarily limited by the scope of his opportunities of observation. When he makes positive statements as to the economical value of deposits of useful minerals, these may be relied on as the results of his inquiries as to the facts; and in all cases of uncertainty, he has endeavoured to avoid everything likely to lead to unfounded hopes or baseless speculations. It has been a source of much gratification to him to find that the First Edition of this Work

has had an important influence on the recent rapid development of the mineral resources of his native country; and he hopes that the present Edition will prove still more extensively useful; and, in any case, that it will be received in the spirit in which it is offered, as a contribution toward the progress of Acadia, from one of her sons.

In theoretical Geology, the following may be mentioned as points of general interest more fully discussed in this Edition, or which have been introduced into it for the first time:—

(1.) The Pre-historic Human period in Acadia, in comparison with that of Europe.

(2.) The character and origin of the Boulder Clay and Surface Glaciation, in connexion with prevailing theories on these subjects.

(3.) The Flora of the Carboniferous period, more especially with reference to the affinities of the several genera of plants, and their relative importance in relation to the formation of Coal—a subject which will be found more fully illustrated in this work than in any previous publication.

(4.) The still more curious and ancient Devonian Flora as displayed in New Brunswick.

(5.) The Land Animals of the Carboniferous and Devonian periods, of which Acadia has afforded so many examples.

(6.) The peculiarities in the nature and age of the Auriferous Deposits of Nova Scotia.

(7.) The remarkable Primordial Fauna of Southern New Brunswick, and the peculiar development of the Lower Silurian in the eastern slope of North America.

(8.) Descriptions and illustrations of Fossils from the various formations.

I may add that I shall have occasion to show, in the following pages, that the rocks of Acadia have, among other important additions to geological science, contributed the first known indications of Carboniferous Reptiles,* and the only known Carboniferous Enaliosaurian, the only Carboniferous land Shells known, the first Carboniferous Myriapod, the first Devonian Insects, the only well characterized Primordial Fauna in America, and the richest known Devonian Flora.

* 1842, see page 354.

suggests the fact that the present Edition, probably the last which the author will be permitted to issue, merely marks a stage in that progress; and that the time will soon arrive when its imperfections will be revealed by the discovery of new facts, when many things now uncertain may have become plain, and when some things now held as certain will be proved to have been errors. When that time shall come, I trust that those who may build on the foundations which I have laid, if they shall find it necessary to remove some misplaced stone or decaying beam, will make due allowance for the difficulties of the work, and the circumstances under which it was executed.*

Many portions of the Work are intended only for reference. I would therefore advise the reader, when he finds his progress arrested by a dry catalogue, a sectional list, or descriptions of fossils, to pass on to the next readable portion. Should he meet with terms or allusions which are not intelligible, by referring to the General Index he will find their explanation in some other portion of the Work. The Index will also be found very useful to those who desire to refer to the structure of particular localities, the description of fossils, or the notices of useful minerals. A "Classified List of Illustrations," an "Index to Economic Geology," and an "Index to Subjects in General Geology," have been added to the Table of Contents, in order to facilitate such reference.

The lovers of the lighter kind of scientific literature may be disappointed in not finding in this work any incidents of travel or illustrations of the aspects of social life in Acadia. I have been obliged by the pressure of graver and more important matter to resist all temptation to dwell on these; but may perhaps find some future occasion to introduce the public to the incidents and adventures of my geological excursions.

Some explanation may be necessary as to the use of the terms *Canada* and *Acadia* in this volume. While the Work was in preparation, that political change was inaugurated whereby the name of

* In connexion with the latter, I think it only just to myself to state that my note-books contain a large amount of local geological detail, which, however appropriate in the Reports of a Survey, could not be inserted in a Work of this description; and that in the following pages a few lines must often represent facts collected in the arduous labour of days or weeks. Much matter will also be found in the papers which I have published, more especially in the Journal of the Geological Society of London, and which it has been impossible to reproduce here.

Upper Canada was changed to Ontario, that of Lower Canada to Quebec, and the name Canada was extended by the Imperial Parliament to the whole Dominion, including New Brunswick and Nova Scotia. This change of nomenclature the author has found it impossible fully to adopt, in consequence of the necessity established by stubborn geological facts, of comparing Acadia collectively with the remaining provinces of the Dominion of Canada. The reader will therefore kindly understand, that wherever in the following pages the terms Canada and Acadia are used in contradistinction, the former includes the provinces of Ontario and Quebec, the latter the provinces of New Brunswick, Nova Scotia, and Prince Edward Island. In other words, for the purposes of this volume, I regard the Dominion of Canada, with Prince Edward Island, as divisible into the two natural regions of *Canada Proper* and *Acadia*.

I may add that, though, as a Nova Scotian, I must sympathize with the natural indignation of my countrymen, in view of the hasty and, I fear, ill-advised Imperial legislation which has deprived them, for the present at least, of their cherished provincial independence and direct connexion with the mother country, and has attached them to the new and untried Canadian "Dominion," I shall rejoice if the confederation shall result in the effectual extension of the labours of the Canadian Geological Survey, under the able management of my friend Sir William E. Logan, to the whole of British America: a union for scientific purposes, open to none of the objections which may be urged against the recent political changes, and which I strongly advocated in my First Edition.

For myself, I confess that at an earlier period of my life it was a cherished object of ambition with me, that it might be my lot to work out in a public capacity the completion of some, at least, of the departments of geological investigation opened up to me in my native province; but it has been otherwise decreed; and however I may regret the want of that extraneous aid, which would have enabled me to devote myself more completely to original researches, by which my own reputation and the interests of my country might have been advanced, I am yet thankful that I have been enabled to do so much by my own unaided resources, and that I have also been able to assist

and encourage others, who may now carry on the work more effectually in connexion with an organized Geological Survey.

The numerous additional Illustrations in this Edition have been engraved by Mr J. H. Walker of Montreal, principally from my own drawings or from photographs. The post-pliocene fossils are from figures in the Canadian Naturalist; the Carboniferous Brachiopods have been copied from Mr Davidson's figures; the Devonian Insects are from drawings by Mr Scudder; and the Primordial Fossils have been drawn by Mr Smith of the Geological Survey of Canada. By reference to the Classified List of Illustrations, it will be seen that more than two hundred and fifty species of fossils have been figured; and I have added a note referring to the Memoirs which contain illustrations of those new species of fossils noticed but not figured in this Work.

In the Explanation of the Geological Map will be found references to the authorities consulted in its preparation.

M'Gill College, *Montreal*, 1868.

occurring on this island are Lower and Upper Silurian or Upper Silurian and Devonian.

In Nova Scotia I have, as heretofore, trusted principally to my own observations, and to those of Mr Brown in Cape Breton. Valuable corrections of limit lines have been received from Rev. Dr Honeyman, F.G.S.; and I am indebted to Mr J. B. Moore of Montreal, Mr Poole of Glace Bay, Mr Mosely of Halifax, and other friends, for MS. Maps and Sections illustrating the distribution of the Coal formation in Pictou and Cape Breton. I have also, on the Carboniferous districts, consulted the Reports of Professor Lesley and Mr Lyman, and many reports made in the interests of the several Coal Companies.

The Laurentian and Huronian formations in Southern New Brunswick are given according to the latest observations of Mr Matthew and Professor Bailey. Some uncertainty may be supposed to rest on the precise equivalency of these beds with the formations so named in Canada; but that they are below the base of the Silurian, and that they correspond in mineral character with the Laurentian and Huronian, cannot be disputed.

The boundaries of the Lower and Upper Silurian, more especially in Northern and Western New Brunswick, and in Western Nova Scotia and Cape Breton, are still very uncertain, and the limits of the igneous veins and masses occurring among these altered beds are only vaguely known. One colour has been employed to represent all the intrusive rocks associated with the formations older than the Trias. The most important of these is the Granite of the age of the Newer Devonian; but there are also numerous dikes and masses of Syenite, Diorite, Compact Felspar, Porphyry, and Dolerite, some of which may be newer and others older than the Granite. I have endeavoured to indicate some of the more important of these; but there are numerous others of minor dimensions which I have not attempted to delineate; as they could be given correctly only on a large scale, and after more minute surveys of their courses and extent.

In Northern New Brunswick, both Professor Hind and Professor Bailey state that the granitic rocks constitute several bands, traversing the Lower Silurian; but as I do not know the limits of these bands, I have adhered in the main to the colouring on Logan's Map. In Nova Scotia, also, I have no doubt that whenever a detailed

Map shall be prepared, showing the courses and limits of the quartzite and slate bands, of the gneiss and mica-slate, and of the many irregular dikes and masses of granite and other eruptive rocks, it will present an appearance marvellously intricate and complex, in comparison with the broad colouring of the present Map. In the meantime, I have been enabled to improve the limit lines formerly given, by reference to the papers of Dr Honeyman, and the Reports presented to the Government of Nova Scotia by Mr Poole and Mr Campbell, to which I may also refer for a great number of minor details of distribution which I could not introduce in the Map.

The only area in Nova Scotia coloured as Devonian is that of Nictaux and its vicinity in the west. There are, however, at and near the limits of the Silurian and Carboniferous, in the eastern part of the province, many spaces which may be of this age, but which I am not able to separate from the Upper Silurian and Carboniferous, and have therefore left as in the former Map. Areas of this kind occur in Colchester, in Pictou, and, according to Dr Honeyman, in Antigonish, and have been mentioned in the text, though I must leave their delineation on the Map to future and more detailed researches. In the Carboniferous areas I have thought it best not to adopt, as in many recent Maps, a distinct colour for the Lower and Upper Carboniferous; but have included the whole under one tint, as constituting one great geological system. The propriety of this will, I think, be obvious, when it is considered that the lines of separation between the subdivisions of the Carboniferous are not sharp and definite, that marine beds coëval with the Coal formation may readily be confounded with the true Lower Carboniferous, and that new discoveries are constantly being made, which show that more local intermixture of the several members of the Carboniferous exists than had been suspected. The boundary of the Lower Carboniferous has, however, been indicated by a dotted line, and special marks show the position of the principal beds of marine limestone, and of the more important beds of coal.

Considerable beds of interstratified trap occur in the Lower Carboniferous of Nova Scotia and New Brunswick. They are included under the general colouring, in consequence of their small superficial extent, and the uncertainty of their limits. The only

exception is a remarkable band, probably of this age, extending around the Bay de Chaleur, and which is given after Sir William Logan. Many similar beds of trap are believed to exist on the northern margin of the Carboniferous area of New Brunswick.

The northern part of the General Section does not coincide precisely with that of the Map, in consequence of the introduction of several trappean masses not indicated in the colouring of the latter. These are given as they occur in Dr Robb's Section, and may represent interstratified igneous rocks. I have thought it best to leave them as given by Professor Robb, not having myself explored the district.

I may also state that the General Section attached to the Map is intended to give the arrangement of the formations on the large scale only, and makes no pretension to represent the numerous minor undulations and fractures.

CHAPTER XVII.

THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XVIII.

THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XIX.

THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XX.

THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XXI.

THE DEVONIAN PERIOD.

CHAPTER XXII.

THE DEVONIAN PERIOD—*Continued.*

CHAPTER XXIII.

THE UPPER SILURIAN PERIOD.

CHAPTER XXIV.

THE LOWER SILURIAN PERIOD.

CHAPTER VIII.

THE TRIAS—*Continued.*

CHAPTER IX.

CHAPTER X.

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THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XII.

THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XIII.

THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XIV.

THE CARBONIFEROUS PERIOD—*Continued.*

CHAPTER XV.

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CHAPTER XVI.

THE CARBONIFEROUS PERIOD—*Continued.*

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The Huronian and Laurentian Periods.

APPENDIX.

INDEX OF SUBJECTS IN GENERAL GEOLOGY ILLUSTRATED OR DISCUSSED IN THIS VOLUME.

CLASSIFIED LIST OF ILLUSTRATIONS.

I. MAPS.

II. SECTIONS.

III. FOSSILS.

PLANTS.

IV. MISCELLANEOUS.

Note.—Figures of most of the new species of Fossils, noticed and not illustrated in this work, may be found in the Author's Memoirs on these subjects, as follows:—

Carboniferous Plants—Journal of Geological Society of London, vol. xxii.

Devonian Plants—Ibid., vols. xviii. and xix., and Canadian Naturalist and Geologist, 1st Series, vol. vi.

Carboniferous Reptiles, etc.—"Air-breathers of the Coal Period," Montreal and London, 1863, and Canadian Naturalist and Geologist, 1st Series, vol. viii.

region now constituting the provinces of Nova Scotia, New Brunswick, and Prince Edward Island, which still retain Acadia as their poetical appellation, and as a convenient general term for the Lower Provinces of British America as distinguished from Canada. Hence the title "Acadian Geology" is appropriate to this work, not only because that name was first bestowed on Nova Scotia, but because the structure of this province, as exposed in its excellent coast sections, furnishes a key to that of the neighbouring regions, which I have endeavoured to apply to such portions of them as I have explored."

I find, however, that the Commissioners on the Settlement of the North-eastern Boundary had previously given a very different explanation of the name. They say, as quoted by Prof. Hind:—*

"The obscurity which has been thrown in past times over the territorial extent of Acadia, that country of which De Monts received letters patent in 1603, was occasioned by not attending to the Indian origin of the name, and to the repeated transfer of the name to other parts of the country to which the first settlers afterwards removed. Even before the appointment of De la Roche, in 1598, as Lieutenant-General of the country, including those parts adjacent to the Bay of Fundy, the bay into which the St Croix empties itself was known to the Indians of the Moriseet (Maliseet) tribe, which still inhabits New Brunswick, by the name *Peska dum quodiah*, from *Peskadum*, fish, and *Quodiah*, the name of a fish resembling the cod,"—which fish is supposed to be that known as the "Pollock."

They further state that the French softened this word Quodiah into *Quadiac*, *Cadie*, and finally Acadie, while the English have changed it into *Quoddy*, as in the well-known name Passamaquoddy, still applied to the bay above mentioned. Independently of the natural objection of an Acadian to believe in the derivation of this honoured and euphonious name from a word meaning a kind of cod-fish, I had great doubts as to the correctness of this etymology in any respect; and with the view of fortifying myself in the belief of the derivation of my old friend St Pierre, I have applied to the Rev. Mr Rand of Hantsport, Nova Scotia, whose acquaintance with the Micmac and Maliseet languages is second to that of no man living, and am happy to say that he confirms my previous opinion, and illustrates it in many curious ways, so that we need not any longer speak of the meaning and origin of the name Acadia as doubtful.

Mr Rand informs me that the word, in its original form, is *Kady*

* Report on Geology of New Brunswick.

or *Cadie*, and that it is equivalent to "region, field, ground, land, or place;" but that when joined to an adjective, or to a noun with the force of an adjective, it denotes that the place referred to is the appropriate or special place of the object expressed by the noun or noun-adjective. Now, in Micmac, adjectives of this kind are formed by suffixing "a" or "wa" to the noun. Thus, in the word before quoted, *Segubbun* is a ground-nut; *Segubbuna*, of or relating to ground-nuts; and *Segubbuna-kaddy* is the place or region of ground-nuts, or the place in which these are to be found in abundance. The following may be given as examples of actual Indian names formed in this way:—

Soona-Kaddy (*Sunacadie*)—Place of cranberries.

Kata-Kaddy—Eel-ground.

Tulluk-Kaddy (Tracadie)—Probably place of residence; dwelling-place.

Skudakumoochwa-Kaddy—Ghost or spirit land—is the somewhat difficult name of a large island in the Bras d'Or Lake, once used as a burial-ground.

Buna-Kaddy (Bunacadie or Benacadie)—Is the place of bringing forth; a place resorted to by moose at the calving-time.

Segoomuma-Kaddy—Place of Gaspereaux, Gaspereau or Alewife River.

According to Mr Rand, *Quodiah*, or *Codiah*, is merely a modification of Kaddy in the language of the Maliceets, and replacing the other form in certain compounds. Thus:

Nooda-Kwoddy (Noodiquoddy or Winchelsea Harbour)—Is place of seals, or, more literally, place of seal-hunting.

Kookejoo-Kwoddy—Giant-land, or land of giants.

Boonamoo-Kwoddy—Tom-cod ground; and, lastly,—

Pestumoo-Kwoddy—Pollock-ground; which brings us back to Passamaquoddy, and to the learned derivation of the Commissioners, who, as unsuccessful in etymology as in the just settlement of the boundary, have merely changed the meaning of the first component of the word into a general term for fish, and have taken *kwoddy* for the equivalent of *pollock*, very likely because its sound resembled that of cod, or because some Maliceet Indian had rendered the name into his imperfect English by the words "Pollock fish here."

So much for the etymology of Cadie or Quoddy; now as to its application to the large region known as Acadia. Two explanations may be given of this. First, the name may be a mere alteration, as suggested by the Commissioners, of that of the bay which lay at the western

extremity of Acadia, and whose aboriginal people were called by the English the Quoddy Indians, perhaps because of the frequent occurrence of the word in their names of places. This name remains in Quoddy Head, the last point of the United States next to Acadia. Secondly, the name, as suggested by me in the first edition of "Acadian Geology," may have originated in the frequency of names with this termination in the language of the natives. The early settlers were desirous of information as to the localities of useful productions, and in giving such information the aborigines would require so often to use the term "Cadie," that it might very naturally come to be regarded as a general name for the country. I still think the latter explanation the more probable.

Acadia, therefore, signifies primarily a place or region, and, in combination with other words, a place of plenty or abundance. Thus it is not only a beautiful name, which should never have been abandoned for such names as New Brunswick or Nova Scotia, but it is most applicable to a region which is richer in the "chief things of the ancient mountains, the precious things of the lasting hills, and the precious things of the earth and of the deep that coucheth beneath," than any other portion of America of similar dimensions.

Farther, since by those unchanging laws of geological structure and geographical position which the Creator himself has established, this region must always, notwithstanding any artificial arrangements that man may make, remain distinct from Canada on the one hand, and New England on the other, the uame Acadia must live; and I venture to predict that it will yet figure honourably in the history of this western world. The resources of the Acadian provinces must necessarily render them more wealthy and populous than any area of the same extent on the Atlantic coast, from the Bay of Fundy to the Gulf of Mexico, or in the St Lawrence valley, from the sea to the head of the great lakes. Their maritime and mineral resources constitute them the Great Britain of Eastern America; and though merely agricultural capabilities may give some inland and more southern regions a temporary advantage, Acadia will in the end assert its natural pre-eminence.

The above considerations justify me in retaining the title of "Acadian Geology" for the present edition of this work, notwithstanding that the name has been overlooked in the new political constitution recently bestowed on Acadia and Canada by the Parliament of Great Britain; and in which the name "Canada" is extended over the whole of British North America. The title is farther appropriate for a work of this nature, from the circumstance that the

Acadian provinces form a well-marked geological district, distinguished from all the neighbouring parts of America by the enormous and remarkable development within it of rocks of the Carboniferous and Triassic systems.

Nova Scotia, which is in a geological point of view the most important of the Acadian provinces, has not enjoyed the full benefit of a public geological survey, though some preliminary explorations have been made under the auspices of the Government. Yet, its mineral resources have been very extensively developed by mining enterprise, its structure has been somewhat minutely examined, and it has afforded some very important contributions to our knowledge of the earth's geological history. Circumstances of a political character, rather than any want of liberality or scientific zeal on the part of the people, have delayed the public and systematic exploration of the geology and mineral resources of the country; while the possession of useful minerals, deficient in all the neighbouring regions, has made it of necessity one of the most important mining districts in North America. Unfortunately, in one sense, for the colony, its abundant mineral wealth attracted attention at a period when the Government of the mother country was not actuated by the liberal spirit that now characterizes its dealings with its dependencies, and when the rights of the colonists were not so jealously or ably guarded as at present. The valuable minerals were reserved by the Crown, and were leased to an association of British capitalists, who opened the principal deposits of coal, and largely exported their produce, and some of whose agents have zealously and successfully aided in exploring the geology of the country. The Provincial Legislature, however, evinced a very natural disinclination to expend the public money in the examination of deposits in which its constituents had no direct interest, and which long continued to be a fertile subject of controversy with the mining company and the Imperial Government.

These impediments to public action on the subject of geological exploration have now passed away. Arrangements have been entered into between the province and the mother country, in virtue of which the control of the mines will revert to the former on the expiry of the lease. A recent act of the Legislature has empowered the Provincial Government to grant leases of unopened mines to private speculators. The provincial lines of railway have opened up many of the inland mineral districts. Valuable metallic minerals have been discovered in localities which had escaped the reservation; and arrangements have been made with the General Mining Association, which have thrown open the coal districts of the province to mining

enterprise. In all these facts there is promise that the Provincial Government will soon find itself in a position to institute a thorough scientific investigation of the structure and productions of the country, and it is to be hoped that this will be done by competent persons and on a liberal scale; and not, as has been the case in some neighbouring colonies, in a manner too imperfect to afford trustworthy results. The excellent survey of Canada now in progress under Sir W. E. Logan, is a model to the other provinces in this respect; and it is to be hoped that, under the new political constitution provided for these colonies, its benefits may be extended to the whole of British North America.

In the meantime, Nova Scotia may congratulate herself, that the noble monuments of the earth's geological history exposed in her coast cliffs have induced eminent geologists from abroad to occupy themselves with the more interesting parts of the structure of the province, and have cherished a strong taste for geological inquiry among her own sons; and that much has thus been effected as a labour of love, which in other countries would have cost a large expenditure of the public wealth. Much, no doubt, still remains to be done, especially in those districts less fertile in facts interesting to the naturalist; but a glance at the list of publications in the following pages, is sufficient to show how much labour has been voluntarily and gratuitously expended, as well as the importance and interest of the discoveries that have been made.

But though a large amount of valuable information has been accumulated, it is scattered through the numbers of scientific journals and other publications, inaccessible to the general reader, and not easily referred to by the geological student; and it is in its nature fragmentary, and incapable of affording a complete view of the structure of the country. These considerations, and the possession of a mass of unpublished notes which had been accumulating for fourteen years, induced the author, in 1855, to undertake the present work, and to believe that, in doing so, he would render an acceptable service not only to his own countrymen and to the inhabitants of the other Acadian provinces, but to those geologists in Britain and America who may be acquainted with his published papers, and may desire a more complete acquaintance with Acadian geology. Ten years have now elapsed since the publication of the first edition of "Acadian Geology." In that time a great additional quantity of geological information has accumulated,—the science itself has made much progress, and a remarkable development of the mineral wealth of the Acadian provinces has occurred. The author has, it is true,

been removed in the meantime from the scene of his former labours, and now dwells in the great Silurian plain of Lower Canada; but he still retains a lively interest in the geology of his native province, and has endeavoured to carry forward to completion some of the subjects left unfinished in 1855, and to acquaint himself as far as possible with the results of the researches of other observers.

In the edition of 1855, Nova Scotia was not only taken as the typical region for the whole of the Acadian provinces; but the scope of the work was in a great degree limited to that province. In the present edition it has become necessary to take a wider range, more especially in regard to New Brunswick, since the researches of Dr Robb, Professor Bailey, Mr Matthews, Mr Hartt, and Professor Hind, have developed to a remarkable extent the geology of the latter province, and have disclosed there some geological formations of great importance not as yet recognised in Nova Scotia.

The earliest account of the geology of Nova Scotia with which I am acquainted, is contained in an elaborate paper in Silliman's American Journal of Science for 1828, by C. T. Jackson and F. Alger, Esqs., of Boston, United States. Messrs Jackson and Alger directed their attention principally to the trap and red sandstone formations of the western districts, and the interesting crystallized minerals contained in the former; but they also gave a tolerably correct view of the distribution of the rock formations throughout the province, and made the earliest attempt to represent them on a geological map. Their determinations of the minerals of the trap district are accurate, and their catalogue of these minerals still admits of little extension. This paper was published in a separate form in 1832.

An important addition was made to the geology of the province in 1829, in a chapter contributed to Haliburton's History of Nova Scotia, by Messrs Brown and Smith, then exploring the province on behalf of the General Mining Association; and the former of whom has subsequently been one of the most successful investigators of the geology of the coal formation. The article in Haliburton relates principally to the eastern districts, and is chiefly remarkable as containing the most accurate views of the development of the carboniferous system in Nova Scotia promulgated previously to the visit of Sir Charles Lyell in 1842.

In 1836, a volume, entitled "Remarks on the Geology and Mineralogy of Nova Scotia," by A. Gesner, F.G.S., was published in Halifax, and was the first work on the local geology extensively circulated in the province. This work was in great part a popular *resumé* of

the previously published discoveries of Jackson and Alger, but with many additional facts collected by its author in the course of careful examinations of the coasts of the Bay of Fundy, and more hurried journeys in other parts of the province. Gesner's work was of great service in directing popular attention within the province to the subject of geology, and it is still an excellent guide to the localities of interesting mineral specimens. "The Industrial Resources of Nova Scotia," a second work by the same author, was published in 1849.

In 1841, Sir W. E. Logan, now provincial geologist of Canada, made a short tour in Nova Scotia, and contributed a paper on the subject to the Geological Society of London. In 1843, in passing through Nova Scotia on his way to Canada, he visited the South Joggins, and executed the remarkable section which he published in 1845 in his first Report on the Geology of Canada. This section, which includes detailed descriptions and measurements of more than fourteen thousand feet of beds, and occupies sixty-five octavo pages, is a remarkable monument of his industry and powers of observation, and gives a detailed view of nearly the whole thickness of the coal formation of Nova Scotia.

The year 1842 forms an epoch in the history of geology in Nova Scotia. In that year Sir Charles Lyell visited the province, and carefully examined some of the more difficult features of its geological structure, which had baffled or misled previous inquirers. Sir Charles also performed the valuable service of placing in communication with each other, and with the geologists of Great Britain, the inquirers already at work on the geology of the province, and of stimulating their activity, and directing it into the most profitable channels. The writer of the present work gratefully acknowledges his obligations in these respects. The results obtained by Sir Charles, which much modified and enlarged the views previously entertained of the structure of Nova Scotia, were communicated to the Geological Society, and a popular account of them was given in his "Travels in North America."

Since 1842, a great number of papers on the geology of Nova Scotia and the neighbouring provinces have been published in the scientific journals and otherwise. The following list includes such of these as have been consulted in the preparation of this work, arranged according to their dates:—

On the upright Fossil Trees found at different levels in the Coal Strata of Nova Scotia. Lyell, Geol. Proc. iv. pp. 176–178.

On the Coal Formation of Nova Scotia, and on the Age of the Gypsum. Lyell, *ibid.* pp. 184–186.

A Geological Map of Nova Scotia. By A. Gesner, Geol. Proc., p. 186. 4to map.

Geological Excursion in Prince Edward Island. J. W. Dawson, Haszard's Gazette, 1842.

Geological Survey of New Brunswick. A. Gesner. 1839–1843.

On the Geology of Cape Breton. R. Brown, Journal of Geol. Society of London, i. p. 23. 4 woodcuts.

On the Lower Carboniferous or Gypsiferous Formation of Nova Scotia. J. W. Dawson, *ibid.* p. 26. 6 woodcuts.

On the Geology of Cape Breton. R. Brown, *ibid.* p. 207. 3 woodcuts.

On the Newer Coal Formation of the Eastern part of Nova Scotia. Dawson, *ibid.* p. 322. 4to map, 4 woodcuts.

Report on the Geology of Prince Edward Island. A. Gesner. 1846.

Notice of some Fossils found in the Coal Formation of Nova Scotia. Dawson, Geol. Journal, ii. pp. 132–136. 1 woodcut.

Notes on the Fossils communicated by Mr Dawson. Bunbury, *ibid.* pp. 136–139. 1 8vo plate.

On a group of erect Fossil Trees in the Sydney Coal Formation, Cape Breton. R. Brown, *ibid.* pp. 393–396. 3 woodcuts.

Report on the Coal Fields of Caribou Cove and River Inhabitants. Dawson, Journals of the Legislature of Nova Scotia, 1846.

On the Boulder Formation and Superficial Drift of Nova Scotia. Dawson, Abstract, Proceedings of the Royal Society of Edinburgh, 1847.

On the Mode of Occurrence of Gypsum in Nova Scotia. Dawson, Abstract, *ibid.* 1847.

On the Gypsiferous Strata of Cape Dauphin, Cape Breton. R. Brown, Geol. Journ. iii. pp. 257–260. 2 woodcuts.

Description of an upright Lepidodendron, with Stigmaria Roots, Sydney, Cape Breton. R. Brown, Geol. Journ. iv. pp. 46–50. 7 woodcuts.

On the New Red Sandstone of Nova Scotia. Dawson, *ibid.* pp. 50–59. 4to map and section.

On the Colouring Matter of Red Sandstones, and the White Beds associated with them. Dawson, Geol. Journ. v. pp. 25–30.

On the Gypsum of Nova Scotia. Gesner, *ibid.* pp. 129, 130. 1 woodcut.

Notice of the Gypsum of Plaster Cove. Dawson, *ibid.* pp. 335–339. 3 woodcuts.

Description of erect Sigillariæ, Sydney, Cape Breton. R. Brown, *ibid.* pp. 354–360. 9 woodcuts.

On the Lower Coal Measures of the Sydney Coal Field, Cape Breton. R. Brown, Geol. Journ. vi. pp. 115-133. 9 woodcuts.

On the Metamorphic and Metalliferous Rocks of the East of Nova Scotia. Dawson, *ibid.* pp. 347–364. 4 woodcuts.

Notice of the Occurrences of upright Calamites near Pictou, Nova Scotia. Dawson, *ibid.* vii. pp. 194–196. 3 woodcuts.

On a Fossil Fern from Cape Breton. Bunbury, *ibid.* viii. pp. 31–35. 1 plate.

Dr Robb's Notices of the Geology of New Brunswick in Johnston's Report. 1849.

Jackson's Report on the Albert Coal Mine (New Brunswick). 1851.

Deposition of R. C. Taylor, etc., on the Albert Mine. 1851.

Notes on the Red Sandstone of Nova Scotia. Dawson, Geol. Journ. pp. 398–400. 2 woodcuts.

On the Remains of a Reptile and a Land-shell in an erect Fossil Tree in the Coal Measures of Nova Scotia. Lyell, Dawson, Wyman, and Owen, Geol. Journ. ix. pp. 58–67. 3 plates, 1 woodcut.

On the Albert Mine, New Brunswick. Dawson, *ibid.* pp. 107–115. 7 woodcuts.

On the Coal Measures of the South Joggins. Dawson, *ibid.* x. pp. 1–42. 25 woodcuts.

On the Structure of the Albion Coal Measures. Dawson; with Journals of Exploratory Works, by H. Poole. *Ibid.* x. pp. 42–47.

On a Fossil imbedded in a mass of Pictou Coal. Professor Owen, *ibid.* x. pp. 207, 208. Lithographic plate.

Notice of the Discovery of the above-mentioned Reptilian Skull. Dawson, *ibid.* xi. p. 8.

On a Modern Submerged Forest at Fort Lawrence, Nova Scotia. Dawson, *ibid.* xi. p. 119.

Leidy on *Bathygnathus Borealis*, an extinct Saurian of the New Red Sandstone of Prince Edward Island. Proc. Ac. Nat. Sci. Phila. 1854.

On the Lower Carboniferous Coal Measures of British America. Dawson, Journ. of Geol. Soc. xv. p. 62.

On the Vegetable Structures in Coal. Dawson, lithog. plates, *ibid.* xv. p. 626.

On a Terrestrial Mollusk, a Millepede, and new Reptiles, from the Coal Formation of Nova Scotia. Dawson, *ibid.* xvi. p. 268.

On an Undescribed Fossil Fern. Dawson, *ibid.* xvii. p. 5.

On Elevations and Depressions of the Earth in North America. Gesner, *ibid.* xvii. p. 381.

On a new Starfish of the Genus Palæaster from Nova Scotia. Billings, woodcut, Canad. Naturalist, v. p. 69.

On the Silurian and Devonian Rocks of Nova Scotia. Dawson, woodcuts, *ibid.* v. p. 132.

On the Coal Field of Pictou. Poole, Can. Nat. v. p. 285.

On new Localities of Fossiliferous Silurian Rocks in Nova Scotia. Honeyman, *ibid.* v. p. 293.

On Natro-Boro-Calcite. How, Ed. Phil. Journ., and Silliman, 1857.

On Faroelite and other Minerals. How, *ibid.* 1858.

On Analysis of three new Minerals from the Trap of the Bay of Fundy. How, *ibid.* 1859.

On the Oil Coal of Nova Scotia. How, Silliman's Journ., 2d ser. xxx. p. 74.

Notice of Additional Reptilian Remains from the Coal of Nova Scotia. Dawson, Journ. Geol. Soc. xviii. p. 5.

Note on a Carpolite and an erect Sigillaria from Nova Scotia. Dawson, Journ. Geol. Soc. xvii. p. 522.

On the Pre-Carboniferous Flora of New Brunswick, Maine, and Eastern Canada. Dawson, Canad. Naturalist, vi. p. 161.

On the recent Discoveries of Gold in Nova Scotia. Dawson, *ibid.* vi. p. 417.

On Natro-Boro-Calcite from Nova Scotia. How, Silliman's Journ., 2d ser. xxxii. p. 9.

On Gyrolite. How, *ibid.* xxxii. p. 13.

On Gold in Nova Scotia. Marsh, *ibid.* xxxii. p. 395.

Remains of an Enaliosaurian in the Coal Formation of Nova Scotia, 1 plate. Marsh, *ibid.* xxxiv. p. 1, and Journal of Geol. Soc. xix. p. 52.

On the Flora of the Devonian Period in N.-E. America. Dawson, Journ. Geol. Soc. xviii. p. 296.

On the Geology of the Gold Fields of Nova Scotia. Honeyman, *ibid.* xviii. p. 342.

On the Lower Carboniferous Brachiopoda of Nova Scotia. Davidson, *ibid.* xix. p. 188.

On New Crustaceans from the Carboniferous and Devonian Rocks of British America. Salter, *ibid.* xix. p. 75.

Further Observations on the Devonian Plants of Maine, Gaspé, and New York. Dawson, *ibid.* xix. p. 458.

On a new Species of *Dendrerpeton*, and on Dermal Coverings of Fossil Reptiles. Dawson, *ibid.* xix. p. 469.

On a new Species of *Phillipsia* from Nova Scotia. Billings, Can. Nat. viii. p. 209.

On the Geology of St John County, New Brunswick. Matthew, Can. Nat. viii. p. 241.

On the Mineral Waters of Nova Scotia. How, *ibid.* viii. p. 370.

On the Footprints of a Reptile from the Coal Formation of Cape Breton. Dawson, *ibid.* viii. p. 430.

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On Mineral Localities in Nova Scotia. Marsh, Silliman's Journ., 2d series, xxv. p. 210.

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Air-Breathers of the Coal Period. Dawson, *ibid.* 1st series, viii. p. 1, etc.; and in separate Work. 6 plates, Montreal, 1863.

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Gold Mines and Gold Mining in Nova Scotia. Perley, Can. Nat. new series, ii. 198.

On the Azoic and Palæozoic Rocks of New Brunswick. Matthew, Journ. Geol. Soc. xxi. p. 422.

On the Albert Coal of New Brunswick. Hitchcock, Silliman's Journ., 2d series, xxxix. p. 267.

On the Conditions of Accumulation of Coal, and on the Coal Flora of Nova Scotia and New Brunswick. 8 plates. Dawson, Journ. Geol. Soc. xxii. p. 95.

On Characteristic Fossils of the Coal Seams of Nova Scotia. Poole, Trans. N. S. Inst. i. p. 30.

Gold and its Separation from other Metals. Gesner, *ibid.* p. 54.

On a Trilobite from the Lower Carboniferous Formations of Nova Scotia. How, *ibid.* 87.

On the Waters of the Mineral Springs of Wilmot. How, *ibid.* ii. p. 26.

The Rocks in the Vicinity of Halifax. Gossip, *ibid.* p. 44.

Notes on the Economic Mineralogy of Nova Scotia, parts 1, 2, and 3, How, *ibid.* p. 78.

On some Brine Springs of Nova Scotia. How, *ibid.* p. 75.

CHAPTER II.

GENERAL DESCRIPTION OF THE ACADIAN PROVINCES—TABULAR ARRANGEMENT OF FORMATIONS.

LET the reader glance at the map, and he will readily perceive some of the principal physical features of the region we have to describe. Nova Scotia consists of a peninsula and island, situated between north latitude 43° 25′ and 47°, and between west longitude 59° 40′ and 66° 25′; and bounded on the south-eastern side by the Atlantic, and on the western and northern sides by the Bay of Fundy, New Brunswick, and the Gulf of St Lawrence. The peninsular part, Nova Scotia proper, is 250 miles in length, and about 100 in its extreme breadth, and is attached to the mainland of North America by a low isthmus sixteen miles in width. Its form is nearly triangular, and its surface is occupied by several rock formations, arranged for the most part in lines corresponding with its longest or Atlantic coast line. The insular part, Cape Breton, barely separated from the mainland by the narrow strait of Canseau, is 100 miles in extreme length and eighty in breadth; and its rock formations are similar to those of Nova Scotia proper, though more irregularly distributed.

The three sides of the triangle formed by Nova Scotia proper are, as seen on the map, distinguished by marked differences of outline. That fronting the north-west is deeply indented by large arms of the sea, separated by precipitous promontories. The longest side, that facing the Atlantic, is dotted with innumerable islands, and penetrated everywhere by small inlets and indentations. The northern shore, fronting the Gulf of St Lawrence, is comparatively smooth and uniform in its coast lines. This is also the character of the eastern coast of Cape Breton; while its remaining sides are very irregular, and its interior is occupied by a lake-like arm of the sea, which, but for the isthmus of St Peter's, less than a mile in width, would cut it into two parts.

It will be observed that the characters of these several coast lines, as well as the different physical districts of the province, are well

marked by the arrangement of the tints which distinguish the different geological formations. The boundaries of these often coincide with those of ranges of hills, and the general direction both of the hills and lines of rock formation is N.E. and S.W., which is the prevailing direction of the structure of the whole eastern part of North America. The whole contour of the country indeed, as well as the directions of its coasts, rivers, and hills, depends on the nature and arrangement of its rocks, and on the elevatory movements to which they have been subjected. The former determine the minor details of the surface and the coast lines: the latter, the elevation and distribution of the rocky masses on the great scale. For illustrations of this, I may refer the reader to the general section annexed to the map, in connexion with the following explanation of the colours representing the several formations.

The carmine and purple portions of the map, representing the oldest rocks in the province—rocks partly ejected in a molten state from the interior of the earth, and partly very ancient sediments metamorphosed or altered by heat and other chemical agencies—extend in an unbroken band along the whole Atlantic coast, wide at its western end, and tapering to a point in the eastern. This belt of country is in some parts low, rugged, and broken, and in others boldly undulating. It is traversed by many rocky ridges, and abounds in lakes, bogs, and streams. Its soils are often sterile and stony, though it has also large tracts of fertile soil, supporting noble forests, and fine agricultural settlements. Its maritime situation and numerous harbours have made it the abode of a large fishing and trading population; and these advantages have also given to it the capital of the province, and several of the most prosperous towns and villages, while its recently discovered gold veins have added to it in recent years great importance as a mining district. This district is low at the Atlantic coast, and gradually rises to the height of a few hundreds of feet at its northern limit, where it descends somewhat suddenly to the level of the inland valleys, which, in the greater part of its length, separate it from the district next to be mentioned.

The very irregular bands and patches, of a blue colour, with carmine lines and spots, also consist of altered rocks, with others of igneous origin, poured through them from beneath; but the whole of somewhat later age than the rocks of the Atlantic coast. This district consists in great part of elevated ridges. It includes the highest and most continuous hills in the province, none of which, however, exceed 1200 feet in height, and the sources of all the

principal rivers. Its hills are covered with fertile soil, and in their natural state support some of the finest forests in the country; and it includes valuable deposits of metallic minerals. Its deep ravines, cascades, and fine wood-clothed precipices, afford the nearest approach to picturesque mountain scenery that a country so little elevated as Nova Scotia can boast.

The portions coloured gray or neutral tint and red represent low and undulating districts, stretching in plains or narrow valleys between and into the higher lands already described. The larger of these, that coloured gray, is the great carboniferous district, including all the valuable deposits of coal, freestone, grindstone, gypsum, and limestone, and having fertile soils over the greater part of its surface. It is therefore the principal abode of the mining, quarrying, and agricultural population. The red district, which is of comparatively small dimensions, represents the New Red Sandstone, a later formation covered by light and productive soil, and containing some of the oldest and finest agricultural settlements.

The long crimson band, extending along the hilly district on the south coast of the Bay of Fundy, and the isolated patches of the same colour on the opposite side of Minas Channel and Basin, are the most recent rocks in Nova Scotia, being masses of volcanic origin which have been poured through the New Red Sandstone formation. They constitute marked and picturesque features in the scenery of the western counties, and along their flanks and on their summits afford fertile soils and support valuable forests.

Lastly, the recent alluvium produced by the tides of the Bay of Fundy, and forming marsh soils of almost inexhaustible fertility, is represented by certain limited stripes and patches of a brown colour.

While, however, each of the geological formations which appear on the map has its special influence on the contour, coast outlines, scenery, and industrial resources of the country, there is a great variety of minor differences within each; for a geological formation, though it often includes a group of rocks characterized, merely as rocks, by many features in common, is distinguished from others, not so much on this ground, as by the period when it was formed, and the fossils characteristic of that period which it contains; consequently we shall often find very dissimilar conditions and mineral productions in neighbouring parts of the same geological district.

If we turn to New Brunswick, we shall find there, with some differences of detail, a repetition of the features of Nova Scotia on a broader and more uniform scale. Stretching along the southern coast, from the head of the Bay of Fundy to the frontier of Maine, is a

belt of ancient and partially altered rocks, forming a somewhat broken and hilly country. At the south-western extremity of the province this belt is joined by another still more extensive, stretching south-westward from the Bay de Chaleur, and forming, with the other, a gigantic letter V, between the arms of which lies the wide triangular area of the New Brunswick coal field; while beyond the northern arm of metamorphic and igneous rocks a plain of unaltered Silurian beds extends to the highlands, along the south side of the St Lawrence. The carboniferous plain of New Brunswick corresponds to, and, at its eastern extremity, is connected with that of Nova Scotia; and its hilly ranges of altered and igneous rocks form, with those of Nova Scotia, outlying ridges rudely parallel to the great Appalachian breastbone of America, and, like it, descending under the level of newer deposits and of the sea at their north-eastern extremities. Where they thus die out and leave the beautifully arched southern bay of the Gulf of St Lawrence, bordered, from Gaspé to Cape Breton, with the coal-bearing rocks, Prince Edward Island bends like a crescent across their extremities, and displays its bright red shores of later age than the carboniferous period, its low but beautifully undulating surface, and its fertile soil unsurpassed in Eastern America.

The whole of this Acadian region is characterized, like other parts of the Atlantic slope of North America, as distinguished from its interior plains, by a varied and uneven surface, and by great variety of soil and mineral products. In the latter, the Acadian provinces are especially rich; and in these and their maritime situation, they bear to the inland regions of Canada much the same relation with that which the British Islands bear to the plains of Central Europe. Nova Scotia, more particularly, is most richly endowed with coal, iron, and gold; and these, with its other resources, its admirable harbours and the hardy and intelligent population, which it possesses in common with the other Acadian provinces, must in time make it the England of North-Eastern America, and must give it an eminence in wealth and influence altogether disproportioned to its limited area.

It is, however, of the nature of mineral wealth such as that of the Acadian provinces, to be more slowly developed than the merely superficial richness of the soil and forests of the great interior plains; and consequently this region has appeared to linger behind Western Canada in its improvement. Its progress, however, is now very rapid, and must proceed at an accelerated rate.

Such being the general physical features of Acadia, it belongs to us, as geologists, to inquire into the structure of its different rock formations, the various materials of which they are composed, the

manner in which they were formed, the periods of the earth's history in which they were produced, and the evidences they afford of the condition of the earth in those periods, the fossils which are embedded in them, and the useful minerals which they contain. No farther introduction will be required to enable the non-geological reader to understand the conclusions arrived at on these subjects, as well as in some degree the manner in which geologists reach these conclusions. Nature, when carefully examined and minutely described, is her own best interpreter; and I have endeavoured so to arrange the subjects treated of as to lead gradually from those modern causes and changes with which nearly all are familiar, to the more ancient natural processes and events, which can be understood only by calling the modern conditions of the earth's surface as witnesses to prove the nature and origin of their predecessors. Fortunately, Nova Scotia affords in its modern deposits many remarkable parallels to the conditions evidenced by its rock formations; and when we fail to discover such analogies within the province, they can generally be obtained by a reference to other countries with which the greater number of intelligent persons are familiar. Should any farther aid be required, it may be obtained by a reference to any of those elementary geological works which are now so numerous and accessible. For these reasons, I shall not detain the reader with any geological information of a general character, other than that contained in the following table, which shows the formations already noticed in connexion with the map and sections, in their relation to the complete geological series, as represented in the rocks of Britain and those of the great mainland of North America.

Tabular View of the Geological Formations of the Acadian Provinces, compared with those of Great Britain, the United States, and Canada.

I. Cainozoic, or Modern and Tertiary.

Formations recognised in the Acadian Provinces.		Representatives in		
		Canada.	United States.	Britain.
Recent.	Peat Bogs, Lake Deposits, Intervales, Marshes, Sand Dunes, etc.	Similar deposits.	Similar deposits.	Similar deposits.
Post-Pliocene.	Terraces, Raised Beaches, and Gravel Ridges.	Saxicava Sand.	River Terraces.	Cave Deposits and River Gravels.
	Marine Clays of St John, etc.	Leda Clay.	Champlain Clay.	Marine Clays.
	Boulder Clay.	Boulder Clay.	Boulder Clay.	Glacial Drift.

I. Cainozoic, or Modern and Tertiary,—*Continued.*

	Formations recognised in the Acadian Provinces.	Canada.	Representatives in United States.	Britain.
Pliocene.	Not found.	Not found.	Newer Tertiaries of Southern States.	Crag, etc.
Miocene.	Not found.	Not found.	Middle Tertiaries of Southern States and Nebraska.	Hempstead Beds, etc.
Eocene.	Not found.	Not found.	Older Tertiaries of Southern and Middle States.	Headon Series, Bagshot Beds, London Clay, etc.

II. Mesozoic, or Secondary.

Cretaceous.	Not found.	Not found.	Greensand and Limestone of New Jersey, Alabama, Texas, Missouri, etc.	Chalk, Gault, Greensand, Wealden.
Jurassic.	Not found.	Not found.	Limestones, etc., of Black Hills, Dakota.	Upper, Middle, and Lower Oolite, and Lias.
Triassic.	Newer Red Sandstone and Trap of Western Nova Scotia, Southern New Brunswick, and Prince Edward Island.	Not found.	Sandstones of Connecticut Valley, etc., Coal Measures of Richmond and Deep River, etc.	White Lias, Saliferous Marls and Newer Red Sandstones of Cheshire, etc.

III. Palæozoic, or Primary.

Permian.	Not represented unless by the lower part of the Sandstones of P. E. Island.	Not found.	Limestone, Marls, etc., of Kansas.	Magnesian Limestone, Marl-Slate, and Lower New Red Sandstone.
Carboniferous.	Upper Coal Formation.	Not found.	Upper Coal Measures.	Coal Formation.
	Middle Coal Formation.	Not found.	Lower Coal Measures.	
	Millstone Grit.	Not found.		Millstone Grit.
	Gypsiferous Series, Limestones, etc. Lower Coal Measures.	Bonaventure Formation.	"Sub-Carboniferous" or Lower Carboniferous.	Carboniferous Limestone. Lower Coal Measures.

III. Palæozoic, or Primary,—*Continued.*

	Formations recognised in the Acadian Provinces.	Representatives in Canada.	United States.	Britain.
Devonian.	Plant-bearing beds of St John, N. Brunswick. Sandstones of Restigouche. Slates, Sandstones, and Iron Ore, of Bear R., Nictaux, etc.	Portage & Chemung Series.* Hamilton „ Corniferous Limestone „ Oriskany „	Portage and Chemung. Hamilton. Upper Helderberg. Oriskany.	Upper, Middle, and Lower Devonian.
Upper Silurian.	Upper Arisaig Series. (Cobequid Mt. Series.) Limestones, etc., of Dalhousie and Restigouche. New Canaan Slates, etc. Lower Arisaig Series. (Kingston Series, N. B.)	Lower Helderberg Series. Onondaga „ Guelph „ Niagara „ Clinton „ Medina „ (Anticosti Gr.)	Lower Helderberg. Salina. Niagara. Clinton. Medina and Oneida.	Upr & Lower Ludlow. Wenlock Limestone and Shale. Upper and Lower Llandovery.
Lower Silurian.	Upper Members not found.	Hudson R. Ser. Utica „ Trenton „ Black R. „	Hudson R. Utica. Trenton. Black R.	Caradoc and Bala.
	Atlantic Coast Metamorphic Series, and Metamorphic Band of Northern New Brunswick.	Chazy „ Quebec „ Calciferous. U. Potsdam.	Chazy. Quebec. Calciferous. U. Potsdam.	Llandeilo. Tremadoc.
	St John, or Acadian Series.	L. Potsdam.	L. Potsdam.	Lingula Flags.
Cambrian.	Coldbrook Group, N. B.	Huronian Series.	Huronian Series.	Longmynd Series.

IV. Eozoic, or Laurentian.

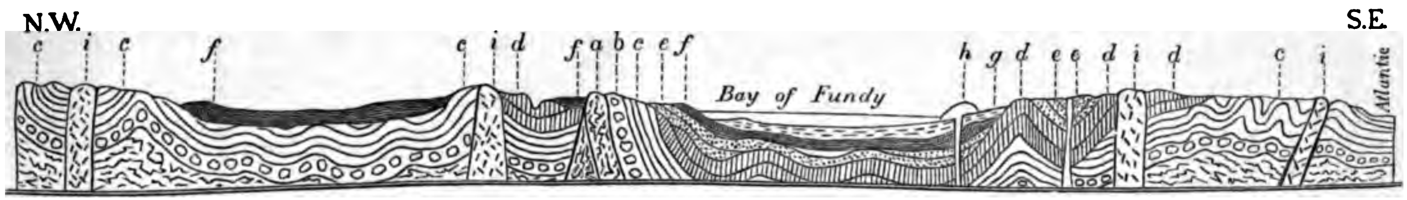
Laurentian.	Portland Series. St John, N. B.	Upper Laurentian. Lower Laurentian.	Adirondack Series.	Gneiss, etc., of the Hebrides.

In the above Table the formations of Canada have been taken from Logan's Report, those of the United States from Dana, and those of Great Britain from Murchison and Lyell.

* In Eastern Canada, Gaspé Sandstones.

GENERALIZED SECTION OF THE ROCKS OF ACADIA,

ON A LINE FROM WOODSTOCK, NEW BRUNSWICK, TO MAHONE BAY, NOVA SCOTIA.



a, Laurentian.
b, Huronian.
c, Lower Silurian.
d, Upper Silurian.
e, Devonian.
f, Carboniferous.
g, Trias.
h, Triassic Trap.
i, Granitic Rocks.

[The above Section represents the view entertained at present by the author as to the probable general arrangement of the formations described in this volume. It is of course an ideal section, and many of the facts represented admit of different interpretations.]

tide: its retreat commences, and the waters rush back as rapidly as they entered.

The rising tide sweeps away the fine material from every exposed bank and cliff, and becomes loaded with mud and extremely fine sand, which, as it stagnates at high water, it deposits in a thin layer on the surface of the flats. This layer, which may vary in thickness from a quarter of an inch to a quarter of a line, is coarser and thicker at the outer edge of the flats than nearer the shore; and hence these flats, as well as the marshes, are usually higher near the channels than at their inner edge. From the same cause,—the more rapid deposition of the coarser sediment,—the lower side of the layer is arenaceous, and sometimes dotted over with films of mica, while the upper side is fine and slimy, and when dry has a shining and polished surface. The falling tide has little effect on these deposits, and hence the gradual growth of the flats, until they reach such a height that they can be overflowed only by the high spring tides. They then become natural or salt marsh, covered with the coarse grasses and *Carices* which grow in such places. So far the process is carried on by the hand of nature; and before the colonization of Nova Scotia, there were large tracts of this grassy alluvium to excite the wonder and delight of the first settlers on the shores of the Bay of Fundy. Man, however, carries the land-making process farther; and by diking and draining, excludes the sea water, and produces a soil capable of yielding for an indefinite period, without manure, the most valuable cultivated grains and grasses. Already there are in Nova Scotia more than forty thousand acres of diked marsh, or "dike," as it is more shortly called, the average value of which cannot be estimated at less than twenty pounds currency per acre. The undiked flats, bare at low tide, are of immensely greater extent.

The differences in the nature of the deposit in different parts of the flats, already noticed, produce an important difference in the character of the marsh soils. In the higher parts of the marshes, near the channels, the soil is red and comparatively friable. In the lower parts, and especially near the edge of the upland, it passes into a gray or bluish clay called "blue dike," or, from the circumstance of its containing many vegetable fragments and fibres, "corky dike." These two varieties of marsh differ very materially in their agricultural value. It often happens, however, that in the growth of the deposit, portions of blue marsh become buried under red deposits, so that, on digging, two layers or strata are found markedly different from each other in colour and other properties; and this change may be artificially produced by digging channels to admit the turbid red waters to overflow the low blue marsh.

and other upland plants, the seeds of which must have been washed into the sea by streams and deposited with the mud.

The low or inner marsh, which I have previously mentioned under its other names of blue marsh and corky dike, is much less valuable than the red. It contains, however, much more vegetable matter, and sometimes approaches to the character of a boggy swamp; so that when a quantity of it is taken out and spread over the upland, it forms a useful manure. It emits a fetid smell when recently turned up, and the water oozing from it stains the ground of a rusty colour. It produces in its natural state crops of coarse grass, but when broken up is unproductive, with the sole exception that rank crops of oats can sometimes be obtained from it.

The chemical composition of this singular soil, so unlike the red mud from which it is produced, involves some changes which are of interest both in agriculture and geology. The red marsh derives its colour from the peroxide of iron. In the gray or blue marsh, the iron exists in the state of a sulphuret, as may easily be proved by exposing a piece of it to a red heat, when a strong sulphurous odour is exhaled, and the red colour is restored. The change is produced by the action of the animal and vegetable matters present in the mud. These in their decay have a strong affinity for oxygen, by virtue of which they decompose the sulphuric acid present in sea-water in the forms of sulphate of magnesia and sulphate of lime. The sulphur thus liberated enters into combination with hydrogen, obtained from the organic matter or from water, and the product is sulphuretted hydrogen, the gas which gives to the mud its unpleasant smell. This gas, dissolved in the water which permeates the mud, enters into combination with the oxide of iron, producing a sulphuret of iron, which, with the remains of the organic matter, serves to colour the marsh blue or gray. The sulphuret of iron remains unchanged while submerged or water-soaked; but when exposed to the atmosphere, the oxygen of the air acts upon it, and it passes into sulphate of iron or green vitriol,—a substance poisonous to most cultivated crops, and which when dried or exposed to the action of alkaline substances, deposits the hydrated brown oxide of iron. Hence the bad effects of disturbing the blue marsh, and hence also the rusty colour of the water flowing from it. The remedies for this condition of the soil are draining and liming. Draining admits air and removes the saline water; lime decomposes the sulphate of iron, and produces sulphate of lime and oxide of iron, both of which are useful substances to the farmer.*

* Since the publication of the first edition of this work, the blue marsh of Nova Scotia has been extensively improved by this process.

This singular and complicated series of processes, into all the details of which I have not entered, is of especial interest to the geologist, as it explains the causes which have produced the gray colour and abundance of sulphuret of iron observed in many ancient rocks, which, like the blue marsh, have been produced from red sediment, changed in colour by the presence of organic matter. It also explains the origin of those singular stains which, in rocks coloured by iron, so often accompany organic remains, or testify to the former existence of those which have passed away. It farther shows the reason of the paucity of organic remains in red rocks, for the red oxide of iron, when present in excess, tends to corrode and destroy any organic matter which may be present; and on the other hand, an excess of organic matter tends to deoxidise the iron and remove it in a state of solution, or change it into a sulphuret, according to circumstances,—the colour of the sediment being changed in either case.

Much geological interest attaches to the marine alluvium of the Bay of Fundy, from the great breadth of it laid bare at low tide, and the facilities which it in consequence affords for the study of sun-cracks, impressions of rain-drops, foot-prints of animals, and other appearances which we find imitated on many ancient rocks. The genuineness of these ancient traces, as well as their mode of preservation, can be illustrated and proved only by the study of modern deposits. I quote a summary of facts of this kind from a paper on rain-prints by Sir Charles Lyell, who was the first to direct attention to these phenomena as exhibited in the Bay of Fundy.*

"The sediment with which the waters are charged is extremely fine, being derived from the destruction of cliffs of red sandstone and shale, belonging chiefly to the coal measures. On the borders of even the smallest estuaries communicating with a bay, in which the tides rise sixty feet and upwards, large areas are laid dry for nearly a fortnight between the spring and neap tides, and the mud is then baked in summer by a hot sun, so that it becomes solidified and traversed by cracks caused by shrinkage. Portions of the hardened mud may then be taken up and removed without injury. On examining the edges of each slab, we observe numerous layers, formed by successive tides, usually very thin, sometimes only one-tenth of an inch thick,—of unequal thickness, however, because, according to Dr Webster, the night-tides rising a foot higher than the day-tides throw down more sediment. When a shower of rain falls, the highest portion of the mud-covered flat is usually too hard to receive any impressions; while that recently uncovered by the tide, near the water's edge, is too soft. Between

* Journal of London Geological Society, vol. vii. p. 239.

these areas a zone occurs almost as smooth and even as a looking-glass, on which every drop forms a cavity of circular or oval form; and if the shower be transient, these pits retain their shape permanently, being dried by the sun, and being then too firm to be effaced by the action of the succeeding tide, which deposits upon them a new layer of mud. Hence we find on splitting open a slab an inch or more thick, on the upper surface of which the marks of recent rain occur, that an inferior layer, deposited perhaps ten or fourteen tides previously, exhibits on its under surface perfect casts of rain-prints which stand out in relief, the moulds of the same being seen in the layer below."

After mentioning that a continued shower of rain obliterates the more regular impressions, and produces merely a blistered or uneven surface, and describing minutely the characteristics of true rain-marks in their most perfect state, Sir Charles adds :—

"On some of the specimens the winding tubular tracks of worms are seen, which have been bored just beneath the surface. Sometimes the worms have dived beneath the surface, and then reappeared. Occasionally the same mud is traversed by the foot-prints of birds (*Tringa minuta*), and of musk rats, minks, dogs, sheep, and cats. The leaves also of the elm, maple, and oak trees have been scattered by the winds over the soft mud, and having been buried under the deposits of succeeding tides, are found on dividing the layers. When the leaves themselves are removed, very faithful impressions, not only of their outline, but of their minutest veins, are left imprinted on the clay."

We have here a perfect instance, in a modern deposit, of phenomena which we shall have to notice in some of the most ancient rocks; and it is only by such minute studies of existing nature that we can hope to interpret those older appearances. In some very ancient rocks we have impressions of rain-marks, or their casts, on the under surface of the overlying beds, quite similar to those which occur in the alluvial mud of the Bay of Fundy. In these old rocks, also, and especially in the coal formation, we find surfaces netted with sun-cracks precisely like those on the dried surfaces of the modern mud flats, and faithful casts of these taken by the beds next deposited. A still more curious appearance is presented by the rill-marks produced by the flowing of the receding tide, or of rain, down inclined surfaces of mud. The little streamlets flowing together into larger channels, form singular patterns, which may be compared to graceful foliage or to the ramifications of roots, and which have often been mistaken for fossils. In the following figures (Figs. 1, 2, 3) I have endeavoured to represent the surface of a small

rain-marked slab of modern mud, presented to me by Dr Webster, and beside it the casts of rain-drops from the showers which fell in Nova Scotia in the carboniferous period. I have also given specimens of rill-marks and sun-cracks from the coal field of Cape Breton, which are quite similar to those to be seen at low tide in the Bay of Fundy; and farther on will be found representations of worm-tracks and foot-prints of animals found on rocks of the same age, and the mode of formation and preservation of which is explained by these same modern deposits (Figs. 4, 5).

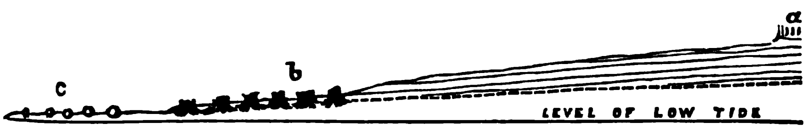
A still more striking geological fact connected with the marshes, is the presence beneath them of stumps of trees still rooted in the soil, and other indications which prove that much if not the whole of this marine alluvium rests on what once was upland soil supporting forest trees; and that, by some change of level, these ancient forests have been submerged and buried under the tidal deposits. To illustrate this, I may notice one of the best instances of these *submarine forests* with which I am acquainted, and which I described in the Journal of the Geological Society in 1854. It occurs on the edge of the marsh near the mouth of the La Planche river, in Cumberland county, at the extremity of Fort Lawrence ridge, which separates the La Planche from the Missaquash, and may be well seen in the neighbourhood of a pier which has recently been erected there.

The upland of Fort Lawrence slopes gently down toward the diked marsh, on crossing which we find, outside the dike, a narrow space of salt marsh thinly covered with coarse grass and samphire (*Salicornia*), and at the outer edge cut away by the neap tides so as to present a perpendicular step about five feet in height. Below this is seen, at low tide, a sloping expanse of red mud, in places cut into furrows by the tides, and in other places covered with patches of soft recently deposited mud. On this slope I saw impressions of rain-drops, sun-cracks, tracks of sandpipers and crows, and abundance of the shells of the little *Tellina Balthica*,* a shell very common in the muddy parts of the Bay of Fundy. There were also a few long straight furrows, still quite distinct in August, but which, I was informed, had been ploughed by the ice in the past spring. At the distance of 326 paces from the abrupt edge of the marsh, and about 25 feet below the level of the highest tides, which here rise in all about 40 feet, I saw the first of the rooted stumps, which appear in a belt of sand, gravel, and stones

* This shell is the *T. Grœnlandica* of some authors, and is *Psammobia fusca* of Say, *Sanguinolaria fusca* of Conrad, *Macoma fusca* of the Smithsonian check-lists.

mixed with mud, which intervenes between the slope of mud already mentioned and the level of low tide. Beyond the stump first seen, and extending to a depth of at least 30 to 35 feet below the level of high tide, other stumps were irregularly scattered as in an open wood. The lowest stump seen was 135 paces beyond the first; and between it and the water level there was a space of 170 paces without stumps, but with scattered fragments of roots and trunks, which may have belonged to rooted trees broken up and swept away by the ice (Fig. 6).

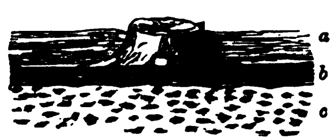
Fig. 6.—*Submarine Forest.—Fort Lawrence.*



(*a*) Marsh. (*b*) Soil with rooted stumps. (*c*) Mud and Stones.

On digging under and around some of the stumps, they were found to be rooted in a soil having all the characters of forest soil. In one place it was a reddish sandy loam, like the ordinary upland of Fort Lawrence: in another place it was a black vegetable soil resting on a white sandy subsoil. Immediately over the soil were the remains of a layer of tough bluish clay, with a few vegetable fibres, apparently rootlets of grasses, which seemed to have been the first layer of marsh mud deposited over the upland soil. All the rootlets of the stumps were entire and covered with their bark, and the appearances were perfectly conclusive as to their being in the place of their growth (Fig. 7).

Fig. 7.—*Stump of Beech in the Submarine Forest.*



(*a*) Mud. (*b*) Vegetable soil. (*c*) Loamy subsoil.

Of thirty or forty stumps which I examined, the greater number were pine (*Pinus strobus*), but a few were beech (*Fagus ferruginea*); and it is worthy of note that these are trees characteristic rather of dry upland than of low or swampy ground. The pine stumps were quite sound, though somewhat softened and discoloured at the surface. The beech, on the other hand, though retaining much

of the appearance of sound wood in the interior, was quite charred at the surface, and was throughout so soft and brittle that large trunks and roots could be cut through with a spade or broken with a slight blow. Owing to their softness, the beech stumps were worn down almost to the level of the mud, while some of the pines projected more than a foot: even these last were, however, much crushed by the pressure of the ice, which, with the tides, must eventually remove them. The largest stump observed was a pine two feet six inches in diameter, and showing more than two hundred annual rings of growth. I was informed by respectable and intelligent persons that similar appearances have been observed on the opposite side of the La Planche, and in various other places in the Cumberland Basin. It is only, however, in places where the marsh is being cut away by the current that they can be seen, and the stumps, when laid bare, are soon removed by the ice. Similar beds of stumps and vegetable soil are also occasionally disclosed in digging ditches in the shallower parts of the marshes, and there appears little reason to doubt that the whole of the Cumberland marshes rest on old upland surfaces. A submerged forest is also said to appear at the mouth of the Folly River in Cobequid Bay; and peaty soils and trunks and stumps of trees are of frequent occurrence in digging in the marshes of King's and Annapolis counties. It would seem, therefore, that these appearances are somewhat general throughout the marsh country.

With respect to the age of these submerged stumps, there can be little difference of opinion. They belong to the modern period in geology, and, judging from the state of preservation of the wood, after making every allowance for the preservative effect of the salt mud, not to the very oldest part of that period. Yet their antiquity is considerable. The marshes are known to have existed in their present state for two hundred and fifty years; and since these trees grew and were submerged, all the mud of the marshes must have accumulated, at least in its present position. Here then we have a modern phenomenon involving great physical changes in the relations of land and water, and rivalling some of those geological events of which we have evidence in the older rocks.

How did this change of the sea level occur? Only two causes can be assigned. It must have been either the rupture of a barrier previously excluding the sea water, or an actual sinking or subsidence of the whole of the western part of the province. The first of these suppositions is that which most readily recommends itself to the popular mind, and we have at no great distance an instance on a

small scale of the effect which might be produced by the rupture of a sea barrier. At the mouth of the St John River, there is a transverse ridge of rock which obstructs the entrance of the tide and the exit of the river water. At low tide, the river water falls outward over the ridge. At about half tide, the water within and that without are on a level. At high tide, there is a strong fall of the tide water inward. Without the barrier, the tide rises from twenty to twenty-five feet; within, it raises the level of the water only about four feet. Now there can be no question that, if this barrier were removed, the tide would daily raise the river to a height which it now attains only in times of flood, while at low tide it would be laid dry to a great depth. If such a change had occurred at some former period, marshes might be found to exist in places which had at one time supported terrestrial plants. Against the application of this explanation, however, to the submarine forests of the Bay of Fundy, we have the great extent of the barrier required, the absence of any existing remains of it, and the great depth below high water at which the remains exist; as it is difficult to suppose that the existence of any barrier, even if it wholly excluded the tide, could produce dry upland at such a level. The effect would rather be the production of a lake, or, at the utmost, of a morass. For these reasons it can scarcely be supposed that any cause of this kind can apply. It only remains to believe that a subsidence has taken place over a considerable area, and to a depth of about forty feet. We have no distinct evidence to show whether this has been sudden or gradual, but analogy would lead us to suppose that it was the latter.

If a gradual subsidence of this kind has occurred in times geologically modern, the question remains, has it ceased, or is the country still subsiding, as Newfoundland and the south of Sweden are supposed to be doing? There are some facts which would seem to indicate that it is. In some localities portions of marsh formerly reclaimed have been abandoned, and it is said that it is now more difficult to maintain the dikes than formerly. We may, however, readily account for all this by supposing that the mud has settled, or that the tides have increased in height or have changed in their direction, in consequence of the contraction of the channels by the diking of new portions of marsh land. We are not therefore under the necessity of arriving at the unpleasant conclusion that our fertile marshes are again settling down beneath the level of the sea, or that the waters of the bay are likely to overflow the upland farms.

I should add, however, that, since the publication of the above

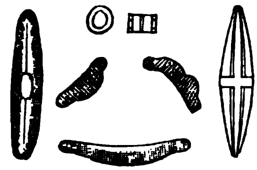
remarks, Professor Cook presented to the meeting of the American Association in Montreal, in 1857, an interesting summary of indications of modern subsidence observed on the coasts of New England, New York, and New Jersey, and estimated the average rate of sinking at two feet in a century, under the impression that it is still in progress, which would coincide with the view above-mentioned as entertained in some parts of the marsh districts of Nova Scotia, that the tides now rise higher than formerly. Additional interest is thus given to the Fort Lawrence instance, as indicating the great vertical amount of this very extensive subsidence. In 1861 also, Dr Gesner, in his paper on "Elevations and Depressions of the Earth in North America," noticed several additional instances of modern submergence in various parts of the British Provinces and the United States, and inferred that such submergence is still in progress, or, at least, has occurred in very recent times. Within the limits of Acadia, and in addition to the examples above referred to, he mentions Grand Manan, Bay Verte, Louisburg in Cape Breton, and Cascumpec in Prince Edward Island, as places in which there is evidence of subsidence since the European colonization of the country.

I would ask the non-geological reader to pause here, to remark that, in the mud-deposits of the Bay of Fundy, we have an example of a geological formation enclosing remains and traces of several of the animals and plants now inhabiting the land or its shores; and that if, in consequence of the colonization of the country, or any physical change, these creatures or any of them were to become extinct, we might find, in digging into the marshes or by examining their borders, evidence of the former existence of such extinct animals or plants, just as the remains of the now extinct European beaver and Irish gigantic stag are found in the peat bogs and lake deposits of Great Britain. Farther, we have in the submarine forests the evidence of extensive changes of level; and if we suppose that, by such changes occurring in the future, the marshes were to be buried under new deposits until they had been consolidated into rock by pressure, by aqueous infiltration of mineral substances, or by internal heat, and then elevated again to the surface, we should discover in their hardened masses a variety of fossils, which, if properly interpreted, would throw much light on the present condition of the country. By bearing in mind these obvious conclusions, much time and perplexity may be avoided, when we arrive at the consideration of ancient formations to which changes of these kinds have actually happened.

than half, of the whole number. The mud forming in the bottoms of these lakes must contain large quantities of the remains of fresh-water fishes, shell-fish, and other animals, as well as of terrestrial quadrupeds that have been drowned in them or killed on their margins; and should these lakes be artificially drained, such remains may excite much interest. At present, however, I shall refer to only one kind of lake deposit, which is curious as an evidence of the large quantity of matter that may be accumulated by the growth and death of successive generations of creatures too small to be observed individually except by the microscope. This is the substance known to naturalists as *Infusorial earth*, and which has been found to abound not only in the deposits from modern waters, but in some ancient rocks, of which it appears indeed sometimes to form the mass. It is, as found in Nova Scotia, a white and, when dry, very light friable earth, having a floury texture, and showing, when examined in a bright light, an infinity of minute shining specks. A little of it diffused in a drop of water, and viewed through a powerful microscope, presents thousands of curiously formed cylindrical, bow-shaped, and rounded transparent bodies, which consist of pure silica or flint, and are the coatings which strengthened the cell-walls of certain minute organisms at one time regarded as animals, but now as one-celled plants of the family *Diatomaceæ*. They grow in the waters of some of our lakes in such numbers that their indestructible silicious coverings, in the course of time, accumulate in layers several feet in thickness. The hardness, sharpness, and minute size of these shells render the mass composed of them useful as a polishing material; the best tripoli being, in fact, an earth of this description. The only specimens of this infusorial earth in my possession, and found in Nova Scotia, are from lakes in the hills of Earlton and Cornwallis. That from the last-named locality is the finer of the two. It was discovered by Dr Webster of Kentville. The late Professor Bailey of West Point, the well-known microscopist, to whom I forwarded specimens from one of the above-named localities, states* that the species contained in it are common to Nova Scotia and the northern parts of the United States. He mentions the following as occurring in specimens from Nova Scotia:—*Pinnularia viridis, P. inæqualis, Cocconema cymbeforme, Gallionella distans, Eunotia monodon, etc., Himantidium arcus, Gomphonema acuminatum, Surirella splendida, Stauroneis Bayleii; Spongiolites, etc.* Some of these species are represented in Fig. 8.

* Silliman's Journal, vol. xlviii.

Fig. 8.—*Coverings of Diatomaceæ from Recent Fresh-water Deposits, Nova Scotia,—magnified.*



Lake Margins in Nova Scotia are of some geological interest, from the effects of ice-pressure which they exhibit. The expansion of the thick icy sheet which forms on the surface of our lakes in winter, and its drifting to and fro when loosened from the shores by the thaws of spring, heap up very remarkable ridges and embankments of stones, gravel, and earth. In low and muddy shores, these actions of the ice, I believe principally the latter, push up long mounds, which look as if an attempt had been made to raise an artificial dike; and where the shores consist of small stones and gravel, still more regular structures are sometimes produced. Occasionally there are two mounds, one within the other, marking different levels of the water; and I have seen these mounds still remaining, in places where lakes and ponds had been long since filled up and converted into bogs. On rocky shores, large stones are pushed against the bank and packed together until they form huge sloping Cyclopean walls, which testify not only by their mass, but by the manner in which they have been wedged together, to the force that has been applied to them. This last appearance is as well seen in some of the upper lakes of the Shubenacadie as in any others that I have examined. These modern effects of ice-pressure will serve to explain some of the phenomena of the drift or boulder formation which overspreads the surface of the province. They are also curious from the resemblance which they bear to glacier moraines, for which they might, in some cases, be easily mistaken.

Bogs and *peaty swamps* form another class of modern deposits which I may notice here. They are very numerous in Nova Scotia, especially in the rocky districts of the Atlantic coast. The largest that I have observed are the Savannahs near Clyde River in Shelburne, and the Carriboo bog of Aylesford. With respect to the geological features of these deposits, I may notice: First, That they consist of vegetable matter which has grown on the spot, and has accumulated, because in water-soaked soils the decay of dead vegetable substances proceeds more slowly than the acquisition of new

matter by growing vegetation from the air and water. Secondly, The vegetable matter in bogs, forming a black carbonaceous mass, has entered on the first stage of the changes by which it may be converted into coal; and it is not unusual to find in the bottom of such bogs a substance much resembling ordinary bituminous coal. Thirdly, The organic acids produced by the vegetable matter, when long saturated in water, remove from the subsoil of the bogs the oxides of iron and manganese, as well as lime and the other alkaline earths; hence the subsoils of bogs usually consist of bleached whitish sand or clay of a very unproductive character. There are a few exceptions to this in localities where the soil contains a very large proportion of lime. On the other hand, when the underlying rocks contain bi-sulphuret of iron, as is the case in some parts of the slate districts, the sulphuric acid produced from this mineral gives a still greater degree of acidity to the bog, while the iron is sometimes in too great quantity to be removed entirely. Fourthly, The iron and manganese, removed in the manner above mentioned, are deposited, usually in rounded kernels, at the outlets of such bogs, or in the soils through which their waters soak, and become partially exposed to the air. In this way small quantities of bog iron ore and bog manganese ore are formed in the vicinity of many swamps. All these facts respecting bogs have their analogues on a large scale in our ancient rock formations, and more especially in those of the carboniferous system.

The bogs when drained, and their surface dressed with sand, or sand and lime, to supply the silicious and calcareous matter in which they are deficient, are excellent soils, second only to diked marsh in their productiveness in hay and oats. Portions of bog have already been reclaimed in this way in several of the counties, and there can be no doubt that many tracts of this description, more especially in the less fertile portions of the province, require only the application of skill and industry to render them valuable.

In describing the modern deposits, I should not omit those of blown sand, which occur somewhat extensively within the region to which this work relates. *Sable Island* is the highest part of one of those banks of sand, pebbles, and fragments of shells and coral, which form a line extending under the waters of the Atlantic, and parallel to the American coast, from Newfoundland to the vicinity of Cape Cod; and which are separated from the coast and from each other by valleys of mud. Sable Island Bank is one of the largest of these submarine sand-beds. Its area is equal to one-third of that of Nova Scotia. The depth of water at its margins varies from 35 to

The following facts, which have a geological as well as a zoological interest, are collected from an interesting lecture on Sable Island, by Dr Gilpin of Halifax.* The walrus, or seahorse (*Trichecus rosmarus*), at one time inhabited the island, but is now extinct, probably in consequence of the attacks of man, since as many as three hundred pairs of teeth are mentioned as being collected on the island. This would seem to have been the most southern range of the walrus, and it is an interesting fact that this arctic creature should come as far south as lat. 44°, on an island to which the Gulf Stream wafts many southern marine forms, such as *Spirula Peronii* and others mentioned by Mr Willis in his list of the shells of Sable Island. The explanation of this curious fact is no doubt to be found in the circumstance that the Sable Island banks form a meeting-place of the ice-laden Arctic Current and the Gulf Stream. The former has brought the walrus and the Greenland seal, which still lives on the island, and many boreal mollusks; the latter drifts to the shores of Sable Island many of the products of more southern latitudes, which may have become mixed in the same deposits with their arctic contemporaries. The only land quadruped mentioned as native to the island is a "black fox," but of what species is uncertain, as the creature seems to be extinct. Horses have been introduced, at what time is uncertain, and have produced the present wild ponies of the island. Their size is small, and their colours "Isabella" and gray, while they have the "large head, thick shaggy neck, low withers, and sloping quarters," usual in wild horses. The rabbit is of recent introduction, and appears to thrive, and to revert to the colour of the wild gray variety of England. The white owl (*Nyctea nivea*) is said to have made its first appearance in 1827, and to have visited the island periodically ever since.

Sand hills and beaches exist in many parts of Nova Scotia and New Brunswick; but nowhere to so great an extent as on the northern side of Prince Edward Island, where the sand resulting from the waste of the soft red sandstones of the island has been moved upward by the waves, and blown by the wind until it forms long ranges of sand-dunes, extending along the coast and crossing the bays, but I believe in no place penetrating far inland; though, since the forest has been cleared, the sand is becoming troublesome on some parts of the coast farms. Across Cascumpec and Richmond bays, and along the intervening coast, a nearly continuous range of sand beaches and hills extends for more than twenty miles; and at New London, Rustico, Covehead, Tracadie, and St Peter's Bays, there are similar

* Halifax, 1858.

ranges of sand hills, amounting altogether to about twenty miles more (Fig. 9).

At New London, the only place where I have had an opportunity of examining these sand hills, they attain the height of forty-feet, and are covered with tufts of coarse beach grass. Their northern sides are frequently cut away into escarpments of loose sand; but on the whole they do not appear to be rapidly changing their form or position. The sand is of a gray or light brownish colour, though derived from red sandstone; its superficial coating of red oxide of iron being almost entirely removed by friction.

Fig. 9.—*Sand Hills, New London, P. E. I.*

No part of Nova Scotia or New Brunswick is sufficiently elevated to retain any snow later than April or May. There is, however, a ravine in the North mountain of Granville, opposite Annapolis, in which ice is said to endure throughout the summer. I visited it in April, and so could not have absolute proof of its perfection as an ice-house. It is a deep ravine encumbered by blocks of trap, which have fallen from its sides in landslips; and it appears that the ice which forms between these blocks in winter is sufficiently protected by the sides of the ravine, the dense vegetation and the blocks themselves to be found unchanged even at the end of summer.

Slight earthquake shocks have been felt at rare intervals in several parts of the Acadian provinces. One occurred on the 8th of February 1855, and was observed throughout Nova Scotia and New Brunswick, and as far to the south-west as Boston. Its point of greatest intensity appears to have been at the Bend of the Petit-

codiac, near the extremity of the New Brunswick coast-line of metamorphic hills. At this place there were several shocks, one of them sufficiently severe to damage a brick building, whereas in the other places only one slight shock was experienced. At Pictou and Halifax, the only shock felt occurred a few minutes before 7 A.M., and it appears to have been simultaneous throughout Nova Scotia and New Brunswick.

The earthquake of the 17th October 1860, which was felt throughout Canada and the Northern States, was felt also in New Brunswick; but I believe not so severely as in Canada.

MICMAC HEADS.

FROM PHOTOGRAPHS.

These are given as memorials of a decaying race, which may soon disappear. The woman is believed to be of pure Micmac descent. The young man, her son, has probably a slight intermixture of French blood by the father's side. Both have the typical features of the race.

CHAPTER IV.

THE MODERN PERIOD—*Continued.*

PRE-HISTORIC MAN—RESULTS OF FOREST FIRES.

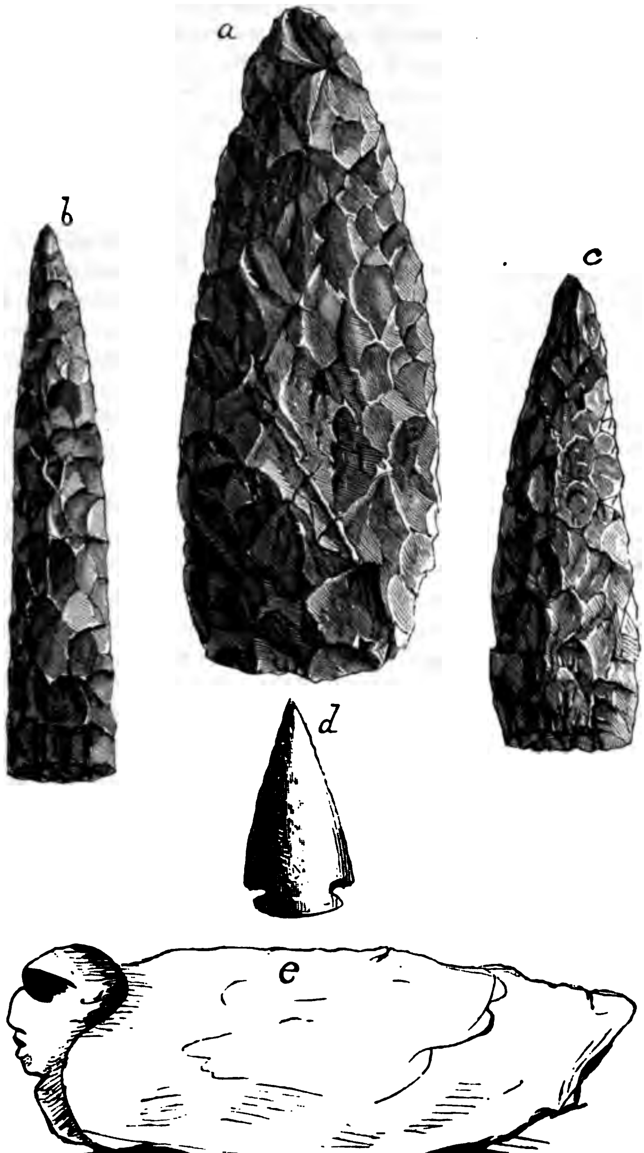
In a region whose history extends backward scarce three hundred years, pre-historic times may seem to have little interest, in so far as the human period is concerned. Yet I think that something may be learned, at a time when pre-historic human remains are exciting so much attention in the old world, by referring to the more recent "Stone Age" of Acadia. Those who speculate as to the antiquity of man, and the ages of Stone, Bronze, and Iron in Europe, and who, looking back on the earlier of these periods through the mists of centuries, attach to it a fabulous antiquity, may derive some lessons from a country in which the stone age existed three hundred years ago, and has yet passed away as completely as though it had never been. The Micmac still pitches his rude wigwam of birch bark within sight of the largest cities of Acadia; but he has entered into the iron age, and the stone weapons of his ancestors are as much objects of curiosity to him as to his neighbours of European origin. When first visited by Europeans, the Micmacs inhabited the coast line of Nova Scotia and New Brunswick, the Malicetes the interior of the latter. Both tribes were of the great Algonquin race, speaking cognate dialects of that widely diffused American tongue which extended along the whole northern side of the St Lawrence valley to Lake Superior. Both tribes were hunters and fishermen, making their canoes and wigwams, as they still do, of the bark of the white birch, and using weapons and other implements of stone and bone. The bronze age never existed in North America; but in Nova Scotia, as in Canada, native copper was used for trinkets, though, from its scarcity, only to a very small extent. The stone implements, as in Canada and the New England states, were both chipped and polished. In the former way were made knives, spear-heads, and arrow-heads, of quartz and flinty slate. In the latter way, chisels, axes, and gouges were made of greenstone and other crystalline rocks. Both varieties were used at the same period for different pur-

poses. The implements represented in Fig. 10 are specimens of the first class, and will serve to show their resemblance to the pre-historic remains of Europe. The large weapon in the middle is the head of a spear or javelin made of hard jaspery slate or fine-grained fissile quartzite. On either side of it are two knives made of a similar material. All three are believed to have been used in a skirmish between the Micmacs and the French, in the early colonization of Nova Scotia. The arrow-head is a beautiful and symmetrical little weapon of pure milky quartz, found in a ploughed field, and of uncertain age. These are good specimens of the Micmac stone implements of the chipped style, and are all of native rocks found in the metamorphic districts of the country. Their implements of polished stone are principally oval or wedge-shaped axes or adzes, often of large size and admirably shaped and smoothed. It would appear from the traditions of these people, as well as from a few historical notices preserved by their earlier visitors, that they carried on wars with the natives of Newfoundland on the north, and of Maine on the south, and with the Mohawks or Iroquois of the St Lawrence; and that, though divided into small tribes, they could form great national leagues for the prosecution of these wars. Their armies were organized under generals and subordinate leaders, and their camps, when in the field, were regularly planned and fortified with palisades interwoven with boughs. The now dwindled remnant of the Micmacs, according to Mr Rand, recall the memory of this stone age of their forefathers as if it were their golden age. Then they were numerous, independent, and powerful. They had fish, game, and clothing in abundance. Their dense forests sheltered them from the winter cold and summer heat. Poverty, want, and disease were comparatively unknown.

How long had this stone age continued? Tradition and history are silent on this point, and, in the nature of the case, monumental evidence fails to give dates. Certain it is, that no discoveries have yet been made pointing to the residence of man in that later Post-Pliocene period in which the Mastodon flourished; and it is probable that the origin of the long-headed or Dolichocephalic race of Eastern America, to which the Micmacs and Malicetes belong, is to be sought for in an ancient immigration from Northern Africa or Europe. The reasons advanced in favour of this view by Retzius,* based on the form of the skull, as compared with that in the Guanches of the Canaries, and the Copts, Moors, etc., are strengthened by the large number of root-words identical with those of the Indo-European

* Archives des Sciences, Geneva, 1860.

Fig. 10.—*Stone Implements, etc.: Figs. a to d one-half natural size.*



languages in the various Algonquin dialects. This subject, to which attention has been called by my friend Mr Rand, has not received the amount of study which it merits, in connexion with the wide diffusion of these root-words over the native languages of Eastern America. Philologists, regarding grammatical construction as alone important, and misled by the superficial dissimilarity of the languages even of neighbouring tribes, have not taken the trouble to search for those deeper resemblances which, even to this day, link the languages of Eastern America with those of the opposite side of the Atlantic.* It is at least certain that the primitive line of migration of the Eastern Americans was northward from the West Indies and Mexico, and that on the shores of the Gulf of St Lawrence they met with another tide of migration coming from the northward and represented by the Esquimaux. Some of the evidences of this have been given in my papers, in the Canadian Naturalist, on the Aboriginal Antiquities of Montreal. I may merely mention here the identity of the manners and customs of the American Indians along the whole east coast up to the limits of the Esquimaux, and the fact that plants native to Mexico, as maize, tobacco, and kidney beans, were cultivated as far north as Quebec. It would seem, therefore, that in these aborigines we have a people whose ancestors migrated from the western part of the old world during the stone age of that region, and, isolated in America, preserved the habits of that primitive period unchanged almost until our own time, presenting us with a perfect picture of a condition of humanity which in the old world has become so obscure as to constitute a field for the wildest speculations and theories. A farther question may be raised, as to the amount of displacements of races in the meeting of different lines of migration, and as to the possibility of any race of men having preceded the Micmacs and Malicetes in Acadia. The Malicetes themselves had a tradition that they migrated eastward from Canada, pressed by the Iroquois population. This is very likely, though it was probably a modern movement, and it may have forced the Micmacs more toward the coast; the latter in this case being perhaps the more primitive people of the two. Both tribes have obscure traditions of certain primitive giants, whom they know by the name *Kookwĕs* (γίγας); but this may be a remnant of traditional lore belonging to the primeval seats of their ancestors in the old world. Carved stones have also been found in New Brunswick, which are unlike anything executed by the more modern tribes, and may have been the work of preceding races. Figure 10 *e* represents one of these stones, found at Harris Cove, on the

* See examples in the Appendix.

the cementing material of the mass; and their wooden handles had been perfectly petrified or converted into a hard fibrous brown limonite, still retaining the structure of the wood. The deposit was probably a *cache* or hiding-place of valuable booty in the early French and Indian wars; and serves, among other things, to show the comparatively perishable character of iron implements as compared with those of stone, and the short space of time which under certain circumstances may give to modern objects the aspect of hoar antiquity.

One of the questions in connexion with pre-historic times which has recently been discussed in Europe, has been the disappearance and renewal of forests in connexion with the succession of races of men. Though the subject was not noticed in the first edition of this work, I had some years previously, in the Edinburgh New Philosophical Journal, directed attention to it, and now reproduce portions of the article, as furnishing useful data to those who, on evidence of this kind, are endeavouring to calculate the antiquity of pre-historic man in Europe.

In their natural state, Nova Scotia and the neighbouring provinces were covered with dense woods, extending from the shores to the summits of the hills. These woods did not form detached groves, but constituted a nearly continuous sheet of foliage, the individual trees composing which were so closely placed as to prevent them from assuming full and rounded forms, and to oblige them to take tall and slender shapes, that each might obtain air and light. The only exceptions to this are certain rich and usually light soils, where the forest is sometimes more open, and hills too rocky to support a covering of trees. When viewed from the summit of a hill, the forest presents a continuous undulating surface of a more or less dark colour and uneven form, in proportion to the prevalence of the deep colours and hard outlines of the evergreen coniferæ, or of the lighter tints and rounded contours of the deciduous trees; and these two classes are usually arranged in belts or irregular patches, containing mixtures of trees corresponding to the fertility and dryness of the soil. In general, the deciduous or hardwood trees prevail on intervale ground, fertile uplands, and the flanks and summits of slaty and trappean hills; while swamps, the less fertile and lightest upland soils, and granitic hills, are chiefly occupied by coniferous trees.

The forest trees spring from a bed of black vegetable mould, whose surface is rendered uneven by the little hillocks of earth and stones thrown up by windfalls; and which, though usually named "*Cradle hills*," are in reality the graves of departed members of the forest, whose trunks have mouldered into the mossy soil. These cradle

hills are most numerous in thin soils; and are chiefly produced by the coniferous trees, and especially by the hemlock spruce. There is usually little underwood in the original forest; mosses, lycopodia, ferns, and a few herbaceous flowering plants, however, flourish beneath the shade of the woods.

The woods perish by the axe and by fire, either purposely applied for their destruction or accidental. Forest fires have not been confined to the period of European occupation. The traditions of the Indians tell of extensive ancient conflagrations; and it is believed that some of the aboriginal names of places in Nova Scotia, for example, *Chebucto*, *Chedabucto*, *Pictou*, originated in these events. In later times, however, fires have been more numerous and destructive. In clearing land, the trees when cut down are always burned; and, that this may be effected as completely as possible, the driest weather is frequently selected, although the fire is then much more likely to spread into the surrounding woods. It frequently happens that the woods contain large quantities of dry branches and tops of trees, left by cutters of timber and firewood, who rarely consider any part of the tree except the trunk worthy of their attention. Even without this preparation, however, the woods may in dry weather be easily inflamed; for although the trunks and foliage of growing trees are not very combustible, the mossy vegetable soil, much resembling peat, burns easily and rapidly. Upon this mossy soil depends, in a great measure, the propagation of fires, the only exception being when the burning of groves of the resinous coniferous trees is assisted by winds, causing the flame to stream through their tops more rapidly than it can pass along the ground. In such cases some of the grandest appearances ever shown by forest fires occur. The fire, spreading for a time along the ground, suddenly rushes up the tall resinous trees with a loud crashing report, and streams far beyond their summits, in columns and streamers of lurid flame. It frequently happens, however, that in wet or swampy ground, where the fire cannot spread around their roots, even the resinous trees refuse to burn; and thus swampy tracts are comparatively secure from fire. In addition to the causes of the progress of fires above referred to, it is probable that at a certain stage of the growth of forests, when the trees have attained to great ages, and are beginning to decay, they are more readily destroyed by accidental conflagrations. In this condition the trees are often much moss-grown, and have much dead and dry wood; and it is probable that we should regard fires arising from natural or accidental causes as the ordinary and appropriate agents for the removal of such worn-out forests.

Where circumstances are favourable to their progress, forest fires may extend over great areas. The great fire which occurred in 1825, in the neighbourhood of the Miramichi River, in New Brunswick, devastated a region 100 miles in length and 50 miles in breadth. One hundred and sixty persons, and more than 800 cattle, besides innumerable wild animals, are said to have perished in this conflagration. In this case, a remarkably dry summer, a light soil easily affected by drought, and a forest composed of full-grown pine trees, concurred, with other causes, in producing a conflagration of unusual extent.

When the fire has passed through a portion of forest, if this consist principally of hardwood trees, they are usually merely scorched,—to such a degree, however, as in most cases to cause their death; some trees, such as the birches, probably from the more inflammable nature of their outer bark, being more easily killed than others. Where the woods consist of softwood or coniferous trees, the fire often leaves nothing but bare trunks and branches, or at most a little foliage, scorched to a rusty-brown colour. In either case, a vast quantity of wood remains unconsumed, and soon becomes sufficiently dry to furnish food for a new conflagration; so that the same portion of forest is liable to be repeatedly burned, until it becomes a bare and desolate "barren," with only a few charred and wasted trunks towering above the blackened surface. This has been the fate of large districts in Nova Scotia and the neighbouring colonies; and as these burned tracts could not be immediately occupied for agricultural purposes, and are diminished in value by the loss of their timber, they have been left to the unaided efforts of nature to restore their original verdure. Before proceeding to consider more particularly the mode in which this restoration is effected, and the appearances by which it is accompanied, I may quote, from a paper by the late Mr Titus Smith of Halifax, a few statements on this subject, which, as the results of long and careful observation, are entitled to much respect, and may form the groundwork for the remarks which are to follow.

"If an acre or two be cut down in the midst of a forest, and then neglected, it will soon be occupied by a growth similar to that which was cut down; but when all the timber on tracts of great size is killed by fires, except certain parts of swamps, a very different growth springs up; at first a great number of herbs and shrubs, which did not grow on the land when covered by living wood. The turfy coat, filled with the decaying fibres of the roots of the trees and plants of the forest, now all killed by the fire, becomes a kind of hot-bed, and seeds which had lain dormant for centuries, spring up

and flourish in the mellow soil. On the most barren portions, the blueberry appears almost everywhere; great fields of red raspberries and fire-weed or French willow, spring up along the edges of the beech and hemlock land, and abundance of redberried elder and wild red cherry appear soon after; but in a few years, the raspberries and most of the herbage disappear, and are followed by a growth of firs, white and yellow birch, and poplar. When a succession of fires has occurred, small shrubs occupy the barren, the *Kalmia*, or sheep-poison, being the most abundant; and, in the course of ten or twelve years, form so much turf, that a thicket of small alder begins to grow, under the shelter of which fir, spruce, hacmetac (larch), and white birch spring up. When the ground is thoroughly shaded by a thicket twenty feet high, the species which originally occupied the ground, begins to prevail, and suffocate the wood which sheltered it; and within sixty years, the land will generally be covered with a young growth of the same kind that it produced of old." Assuming the above statements to be a correct summary of the principal modes in which forests are reproduced, we may proceed to consider them more in detail.

1st, Where the forest trees are merely cut down and not burned, the same description of wood is immediately reproduced. This may be easily accounted for. The soil contains abundance of the seeds of these trees, there are even numerous young plants ready to take the place of those which have been destroyed; and if the trees have been cut in winter, their stumps produce young shoots. Even in cases of this kind, however, a number of shrubs and herbaceous plants, not formerly growing in the place, spring up; the cause of this may be more properly noticed when describing cases of another kind. This simplest mode of the destruction of the forest, may assume another aspect. If the original wood have been of kinds requiring a fertile soil, such as maple or beech, and if this wood be removed, for example, for firewood, it may happen that the quantity of inorganic matter thus removed from the soil may incapacitate it, at least for a long time, from producing the same description of timber. In this case, some species requiring a less fertile soil may occupy the ground. For this reason, forests of beech growing on light soils, when removed for firewood, are sometimes succeeded by spruce and fir. I have observed instances of this kind, both in Nova Scotia and Prince Edward Island.

2dly, When the trees are burned, without the destruction of the whole of the vegetable soil, the woods are reproduced by a more complicated process, which may occupy a number of years. In its first stage, the burned ground bears a luxuriant crop of herbs and

shrubs, which, if it be fertile and not of very great extent, may nearly cover its surface in the summer succeeding the fire. This first growth may comprise a considerable variety of species, which we may divide into three groups. The first of these consists of herbaceous plants, which have their roots so deeply buried in the soil as to escape the effects of the fire. Of this kind are the various species of Trillium, whose tubers are deeply embedded in the black mould of the woods, and whose flowers may sometimes be seen thickly sprinkled over the black surface of woodland very recently burned. Some species of ferns also, in this way, occasionally survive forest fires. A second group is composed of plants whose seeds are readily transported by the wind. Pre-eminent among these is the species of Epilobium known in Nova Scotia as the fire-weed or French willow (*E. angustifolium*), whose feathered seeds are admirably adapted for flying to great distances, and which often covers large tracts of burned ground so completely, that its purple flowers communicate their own colour to the whole surface, when viewed from a distance. This plant appears to prefer the less fertile soils, and the name of fire-weed has been given to it in consequence of its occupying these when their wood has been destroyed by fire. Various species of Senecio, Solidago, and Aster, and Equiseta, Ferns, and Mosses, are also among the first occupants of burned ground; and their presence may be explained in the same way with that of the Epilobium, their seeds and spores being easily scattered over the surface of the barren by wind. A third group of species, found abundantly on burned ground, consists of plants bearing edible fruits. The seeds of these are scattered over the barren by birds which feed on the fruits, and, finding a rich and congenial soil, soon bear abundantly and attract more birds, bringing with them the seeds of other species. In this way, it sometimes happens that a patch of burned ground, only a few acres in extent, may, in a few years, contain specimens of nearly all the fruit-bearing shrubs and herbs indigenous in the country. Among the most common plants which overspread the burned ground in this manner, are the raspberry, which, in good soils, is one of the first to make its appearance; the species of *Vacciniæ*, or whortle-berries and blueberries; the tea-berry or wintergreen (*Gaultheria procumbens*); the pigeon-berry (*Cornus canadensis*); and the wild strawberry. It is not denied that some plants may be found in recently burned districts whose presence may not be explicable in the above modes; but no person acquainted with the facts can deny that nearly all the plants which appear in any considerable quantity within a few years after the occurrence of a fire, may readily be included in the groups which have been mentioned. By the

simple means which have been described, a clothing of vegetation is speedily furnished to the burned district; the unsightliness of its appearance is thus removed, abundant supplies of food are furnished to a great variety of animals, and the fertility of the soil is preserved, until a new forest has time to overspread it.

With the smaller plants which first cover a burned district great numbers of seedling trees spring up, and these, though for a few years not very conspicuous, eventually overtop and, if numerous, suffocate the humbler vegetation. Many of these young trees are of the species which composed the original wood, but the majority are usually different from the former occupants of the soil. The original forest may have consisted of white or red pine; black, white, or hemlock spruce; maple, beech, black or yellow birch, or of other trees of large dimensions, and capable of attaining to a great age. The "second growth" which succeeds these usually consists of poplar, white or poplar birch, wild cherry, balsam fir, scrub pine, alder, and other trees of small stature, and usually of rapid growth, which, in good soils, prepare the way for the larger forest trees, and occupy permanently only the less fertile soils. A few examples will show the contrast which thus appears between the primeval forest and that which succeeds it after a fire. Near the town of Pictou, woods chiefly consisting of beech, maple, and hemlock, have been succeeded by white birch and firs. A clearing in woods of maple and beech in New Annan, at one time under cultivation, was, after thirty years, observed to be thickly covered with poplars thirty feet in height, presenting a striking contrast to the surrounding woods. In Prince Edward Island, fine hardwood forests have been succeeded by fir and spruce. The pine woods of Miramichi, destroyed by the great fire above referred to, have been followed by a second growth, principally composed of white birch, larch, poplar, and wild cherry. When I visited this place, twenty years after the great fire, the second growth had attained to nearly half the height of the dead trunks of the ancient pines, which were still standing in great numbers; and in 1866 I found that the burnt woods were replaced by a dense and luxuriant forest principally of white birch and larch or hacmetac, and I was informed that some of these trees were already sufficiently large to be used in ship-building. This is an instructive illustration of the fact, that after a great forest fire an extensive region may in less than half a century be re-clothed with different species from those by which it was originally covered.

As already stated, the second growth almost always includes many trees similar to those which preceded it, and when the smaller trees

have attained their full height, these, and other trees capable of attaining a greater magnitude, overtop them, and finally cause their death. The forest has then attained its last stage, that of perfect renovation. The cause of the last part of the process evidently is, that in an old forest, trees of the largest size and longest life have a tendency to prevail, to the exclusion of others. For reasons which will be afterwards stated, this last stage is rarely attained by the burned forests in countries beginning to be occupied by civilized man, and it is evident that many circumstances may occur which will prevent this restoration of the primeval forest.

In accounting for the presence of the seeds necessary for the production of the second growth, we may refer to the same causes which supply the seeds of the smaller plants appearing immediately after the fire. The seeds of many forest trees, especially the poplar, the birch, and the firs and spruces, are furnished with ample means for their conveyance through the air. The cottony pappus of the poplar seems especially to adapt it for this purpose. The seeds of the wild cherry, another species of frequent occurrence in woods of the second growth, are dispersed by birds, which are fond of the fruit; the same remark applies to some other fruit-bearing species of less frequent occurrence. When the seeds that are dispersed in these ways fall in the growing woods, they cannot vegetate; but when they are deposited on the comparatively bare surface of a barren, they readily grow; and if the soil is suited to them, the young plants increase in size with great rapidity.

It is possible, however, that the seeds of the trees of the second growth may be already in the soil. It has been already stated, that deeply-buried tubers sometimes escape the effects of fire; and, in the same manner, seeds embedded in the vegetable mould, or buried in cradle hills, may retain their vitality, and, being supplied by the ashes which cover the ground with alkaline solutions well-fitted to promote their vegetation, may spring up before a supply of seed could be furnished from any extraneous source. It is even probable that many of the old forests may already have passed through a rotation similar to that above detailed, and that the seeds deposited by former preparatory growths may retain their vitality, and be called into life by the favourable conditions existing after a fire.

If, as already suggested, forest fires, in the uncultivated state of the country, be a provision for removing old and decaying forests, then such changes as those above detailed must have an important use in the economy of nature, since by their means different portions of the country would succeed each other in assuming the state of

"barrens," producing abundance of herbs and wild fruits suitable for the sustenance of animals which could not subsist in the old woods; and these gradually becoming wooded, would keep up a succession of young and vigorous forests.

3dly, The process of restoration may be interrupted by successive fires. These are most likely to occur soon after the first burning, but may happen at any subsequent stage. The resources of nature are not, however, easily exhausted. When fires pass through young woods, some trees always escape; and so long as any vegetable soil remains, young plants continue to spring up, though not so plentifully as at first. Repeated fires, however, greatly impoverish the soil, since the most valuable part of the ashes is readily removed by rains, and the vegetable mould is entirely consumed. In this case, if the ground be not of great natural fertility, it becomes incapable of supporting a vigorous crop of young trees. It is then permanently occupied by shrubs and herbaceous plants; at least these remain in exclusive possession of the soil for a long period. In this state the burned ground is usually considered a permanent barren,—a name which does not, however, well express its character; for though it may appear bleak and desolate when viewed from a distance, it is a perfect garden of flowering and fruit-bearing plants, and of beautiful mosses and lichens. There are few persons born in the American colonies who cannot recall the memory of happy youthful days spent in gathering flowers and berries in the burnt barrens. Most of the plants already referred to as appearing soon after fires continue to grow in these more permanent barrens. In addition to these, however, a great variety of other plants gradually appear, especially the *Kalmia angustifolia*, or sheep laurel, which often becomes the predominant plant over large tracts. Cattle straying into the barrens deposit the seeds of cultivated plants, as the grasses and clovers, as well as of many exotic weeds, which often grow as luxuriantly as any of the native plants.

Lastly, When the ground is permanently occupied for agricultural purposes, the reproduction of the forest is of course entirely prevented. In this case, the greater number of the smaller plants found in the barrens disappear. Some species, as the Solidagos and Asters, and the Canada thistle, as well as a few smaller plants, remain in the fields, and sometimes become troublesome weeds. The most injurious weeds found in the cultivated ground are not, however, native plants, but foreign species, which have been introduced with the cultivated grains and grasses; the ox-eyed daisy or white weed, and the crowsfoot or buttercup, are two of the most abundant of these.

When a district has undergone this last change,—when the sombre woods and the shade-loving plants that grow beneath them have given place to open fields, clothed with cultivated plants,—the metamorphosis which has taken place extends in its effects to the indigenous animals; and in this department its effects are nearly as conspicuous and important as in relation to vegetation. Some wild animals are incapable of accommodating themselves to the change of circumstances; others at once adapt themselves to new modes of life, and increase greatly in numbers. It was before stated that the barrens, when clothed with shrubs, young trees, and herbaceous plants, were in a condition highly favourable to the support of wild animals; and perhaps there are few species which could not subsist more easily in a country at least partially in this state. For this reason, the transition of a country from the forest state to that of burned barrens is temporarily favourable to many species, which disappear before the progress of cultivation; and this would be more evident than it is, if European colonization did not tend to produce a more destructive warfare against such species than could be carried on by the aborigines. The ruffed grouse, a truly woodland bird, becomes, when unmolested, more numerous on the margins of barrens and clearings than in other parts of the woods. The hare multiplies exceedingly in young second growths of birch. The wild pigeon has its favourite resort in the barrens during a great part of the summer. The moose and cariboo, in summer, find better supplies of food in second growth and barrens than in the old forests. The large quantities of decaying wood, left by fires and wood-cutters, afford more abundant means of subsistence to the tribe of woodpeckers. Many of the fly-catchers, warblers, thrushes, and sparrows, greatly prefer the barrens to most other places. Carnivorous birds and quadrupeds are found in such places in numbers proportioned to the supplies of food which they afford. The number of instances of this kind might be increased to a great extent if necessary; enough has, however, been stated to illustrate the fact.

Nearly all the animals above noticed, and many others, disappear when the country becomes cultivated. There are, however, other species which increase in numbers, and at once adapt themselves to the new conditions introduced by man. The robin (*Turdus migratorius*) resorts to and derives its subsistence from the fields, and greatly multiplies, though much persecuted by sportsmen. The *Junco hyemalis*, a summer bird in Nova Scotia, becomes very familiar, building in outhouses, and frequenting barns in search of food. The song sparrow and Savannah finch swarm in the cultivated ground. The yellow bird (*Sylvia æstiva*) becomes very familiar, often

building in gardens. The golden-winged woodpecker resorts to the cultivated fields, picking grubs and worms from the ground. The cliff-swallow exchanges the faces of rocks for the eaves of barns and houses, and the barn and chimney swallows are everywhere ready to avail themselves of the accommodation afforded by buildings. The Acadian or little owl makes its abode in barns during winter. The bob-lincoln, the king-bird, the waxwing or cherry-bird, and the humming-bird, are among the species which profit by the progress of cultivation. The larger quadrupeds disappear, but the fox and ermine still prowl about the cultivated grounds, and the field-mouse (*Arvicola Pennsylvanica*), which is very abundant in some parts of the woods, is equally so in the fields. Many insects are vastly increased in numbers in consequence of the clearing of the forests. Of this kind are the grasshoppers and locusts, which, in dry seasons, are very destructive to grass and grain; the frog-spittle insects (*Cercopis*), of which several species are found in the fields and gardens, and are very injurious to vegetation; and the Lepidoptera, nearly the whole of which find greater abundance of food and more favourable conditions in the burned barrens and cultivated fields than in the growing woods.

It thus appears that, in the course of between two and three centuries, large areas of the Acadian provinces have passed through two or more of the following conditions:—1. That of primitive forest; 2. That of second-growth forest; 3. That of the burned barren; 4. That of cultivated fields. Each of these changes is accompanied with modifications of the animal population; and in primitive states of society each would imply a change in the habits of the people; and, if very extensive, might even cause migrations of tribes and important changes of population. In the old world, most countries have passed through these vicissitudes in very early times, and have subsequently reached a more stable condition, with more slow and gradual changes; and in extensive regions it has usually happened that the destruction and removal of forests have been effected piecemeal, so as to extend only over limited areas at one time. The case of Denmark would seem to have been an exception to this.* At a very early pre-historic time it seems to have been covered by forests of Scotch fir. These were destroyed, probably by a great fire like that of Miramichi. The people perished or were driven from the country, and were replaced by another race, while the forests grew up again, but were now composed of oak. Still more recently the oak forests were replaced by beech. The stages of unrecorded human history connected in Denmark with these successive forests, are thus summed up by Steenstrup and Morlot:—"1*st*, A *stone*

* Lyell, "Antiquity of Man;" Lubbock, in Nat. Hist. Review.

period, when the inhabitants were small-sized men, brachykephalous or short headed, like the modern Lapps, using stone implements, and subsisting by hunting. Then the country, or a considerable part of it, was covered by forests of Scotch fir (*Pinus sylvestris*). 2*d*, A *bronze period*, in which implements of bronze as well as of stone were used, and the skulls of the people were larger and longer than in the previous period; while the country seems to have been covered with forests of oak (*Quercus robur*). 3*d*, An *iron period*, which lasted to the historic times, and in which beech forests replaced those of oak." All of these remains are geologically recent; and, except the changes in the forests, and of some indigenous animals in consequence, and probably a slight elevation of some parts of Denmark, no material changes in organic or inorganic nature have occurred.

The Danish antiquaries have attempted to calculate the age of the oldest of these deposits by considerations based on the growth of peat, and the succession of trees; but these calculations are obviously unreliable. The first forest of pines would, when it attained maturity, naturally be destroyed, as usually happens in America, by forest conflagrations. It might perish in this way in a single summer. The second growth which succeeded would, in America, be birch, poplar, and similar trees, which would form a new and tall forest in half a century; and in two or three centuries would probably be succeeded by a second permanent forest, which in the present case seems to have been of oak. This would be of longer continuance, and would, independently of human agency, only be replaced by beech, if, in the course of ages, the latter tree proved itself more suitable to the soil, climate, and other conditions. Both oak and beech are of slow extension, their seeds not being carried by the winds, and only to a limited degree by birds. On the other hand, the changes of forests cannot have been absolute or universal. There must have been oak and beech groves even in the pine woods; and the growing and increasing beech woods would be contemporary with the older and decaying oak forest, as this last would probably perish, not by fire, but by decay, and by the competition of the beeches. The growth of peat has also been appealed to in connexion with the succession of forests as affording a mark of time; but this is very variable even in the same locality. It goes on very rapidly when moisture and other conditions are favourable, and especially when it is aided by wind-falls, drift-wood, or beaver-dams, impeding drainage and contributing to the accumulation of vegetable matter. It is retarded and finally terminated by the rise of the surface above the drainage level, by the clearing of the country, or by the establishment of natural or artificial drainage.

On the one hand, all the changes observed in Denmark may have taken place within a minimum time of two thousand years. On the other hand, no one can affirm that either of the three successive forests may not have flourished for that length of time. A chronology measured by years, and based on such data, is evidently worthless; but it is interesting in connexion with our present subject to observe, that the remains preserved in the shell-heaps or "Kjökkenmödding" of the stone age in Denmark indicate a wonderful similarity of habits and customs with those of primitive America, except that the people seem to have borne a closer resemblance to the Esquimaux than to the ordinary American Indian.

On the whole, nothing can be more striking to any one acquainted with the American Indian than the entire similarity of the traces of pre-historic man in Europe to those which remain of the primitive condition of the American aborigines, whether we consider their food, their implements and weapons, or their modes of sepulture; and it seems evident that if these pre-historic remains are ever to be correctly interpreted by European antiquaries, they must avail themselves of American light for their guidance. Much of this light has already been thrown on this subject by my friend Professor Wilson, in his "Prehistoric Man;" but one can scarcely open any European book on this subject, or glance at any of the numerous articles and papers on this fertile theme in scientific journals, without wishing that those who discuss pre-historic man in Europe knew a little more of his analogue in America. The subject is a tempting one, but I must close this notice, already too long for the space I should devote to it, by remarking, that the relations in America of the short-headed and long-headed races of men are by no means dissimilar from those of the two similar races in Europe; while it is also evident that some pre-historic skulls, supposed to be of vast antiquity, as, for instance, that of Engis, bear a very close resemblance to those of the Algonquin and Iroquois Indians.

CHAPTER V.

THE POST-PLIOCENE PERIOD.

UNSTRATIFIED DRIFT—TRAVELLED BOULDERS—STRIATED ROCK SURFACES—PEAT UNDER BOULDER CLAY—ORIGIN OF DRIFT—STRATIFIED GRAVELS—REMAINS OF MASTODON.

THE deposits last described are found in the bed or on the margin of the existing waters, and they rest on the ordinary upland soils, which are consequently older than they. These soils and subsoils, which are often of great depth, and which over a great part of the region under consideration completely hide the rocks which lie beneath, belong to the formations which we are now to describe. The soils and subsoils of any country, so far at least as they consist of mineral matter, are derived from the waste of the rocks of which that country is composed. Hence we are in no way surprised to find the soil overlying sandstone rocks to be sandy, that over shales and slates to consist in great part of clay, or that overlying limestone to be calcareous; and we may attribute such appearances to the mere waste or decay of the underlying rock, by the action of the air, the water, and the frost. This waste may have been proceeding ever since the country emerged from beneath the deep, and need not necessarily belong to one geological period more than to another. But the case becomes very different where we find the soil to consist of or to contain materials for whose presence we cannot account by any causes now in operation in the locality; and this we shall find to be the case with the formations of that time which immediately preceded our Modern epoch, and which we name the Post-Pliocene; but which, from the nature of its deposits, and the conditions which they imply, has also received such names as the drift, the boulder formation, and the glacial period.

If we examine the materials exposed in ordinary excavations, or on the coasts and river banks, and which extend from the surface down to the solid rocks, we find them to consist of clay or sand intermixed with large stones, or occasionally of large stones with their interstices filled with soil, or possibly in a few localities of rolled gravel, like that

found on the beach or in river beds. If our inquiries proceed a little beyond a mere glance at these at first sight not very interesting materials, we may discover that the large stones in the drift are of very different kinds. Some of them, perhaps the greater number, may be of the same kind with the rocks occurring *in situ* in the vicinity. Others are of kinds not found in place except at great distances. It is farther observable that the clay or sand containing large stones, is not arranged in layers, but that its materials are confusedly intermixed. The fine rounded gravel, however, is not only comparatively free from large stones, but it is arranged in beds or layers, often with bands of sand between. We shall also in some localities find beds of fine clay containing marine shells, and sometimes, though rarely, compressed peaty matter underlying the drift deposits.

By studying the superposition of these materials, we may readily arrive at the following arrangement of them in descending order, or from the newer to the older :—

1. Gravel and sand beds, and ancient gravel ridges and beaches, indicating the action of shallow water and strong currents and waves.

2. Stratified clay with shells, showing quiet deposition in deeper water.

3. Unstratified boulder clay, indicating the united action of ice and water.

4. Peaty deposits, belonging to a land surface preceding the deposit of the boulder clay.

As the third of these formations is the most important and generally diffused in Acadia, we shall attend to it first, and notice the relation of the others to it.

The *Unstratified Drift* or boulder clay may be viewed as consisting of a base or paste including angular and rounded fragments of rocks. The base varies from a stiff clay to loose sand, and its composition and colour generally depend upon those of the underlying and neighbouring rocks. Thus, over sandstone it is arenaceous, over shales argillaceous, and over conglomerates and hard slates pebbly or shingly. The greater number of the stones contained in the drift are usually, like the paste containing them, derived from the neighbouring rock formations. These untravelled fragments are often of large size, and are usually angular, except when they are of very soft material, or of rocks whose corners readily weather away. It is unnecessary to give illustrations of these facts. Any one can observe, that on passing from a granitic district to one composed of slate, or from slate to sandstone,

the character of the loose stones changes accordingly. It is also a matter of familiar observation, that in proportion to the hardness or softness of the prevailing rocks, the quantity of these loose stones increases or diminishes. In some of the quartzite and granite districts of the Atlantic coast, the surface seems to be heaped with boulders with only a little soil in their interstices, and every little field, cleared with immense labour, is still half-filled with huge white masses popularly known as "elephants." On the other hand, in the districts of soft sandstone and shale, one may travel some distance without seeing a boulder of considerable size.

Though I have called these fragments untravelled, it by no means follows that they are undisturbed. They have been lifted from their original beds, heaped upon each other in every variety of position, and intermixed with sand and clay, in a manner which shows convincingly that the sorting action of running water had nothing to do with the matter; and this applies not only to stones of moderate size, but to masses of ten feet or more in diameter. It is as if a gigantic harrow had been dragged over the surface, tearing up the solid rocks, and mingling their fragments in a rude and unsorted mass.

Beside the untravelled fragments, the drift always contains boulders derived from distant localities, to which in many cases we can trace them; and I shall mention a few instances of this to show how extensive has been this transport of detritus. In the low country of Cumberland there are few boulders, but of the few that appear, some belong to the hard rocks of the Cobequid Hills to the southward; others may have been derived from the somewhat similar hills of New Brunswick. On the summits of the Cobequid Hills and their northern slopes, we find angular fragments of the sandstones of the plain below, not only drifted from their original sites, but elevated several hundreds of feet above them. To the southward and eastward of the Cobequids, throughout Colchester, Northern Hants, and Pictou, fragments from these hills, usually much rounded, are the most abundant travelled boulders, showing that there has been great driftage from this elevated tract. In like manner, the long ridge of trap rocks extending from Cape Blomidon to Briar Island has sent off great quantities of boulders across the sandstone valley which bounds it on the south, and up the slopes of the slate and granite hills to the southward of this valley. Well characterized fragments of trap from Blomidon may be seen near the town of Windsor; and I have seen unmistakable fragments of similar rock from Digby Neck, on the Tusket River, thirty miles from their original position. On the other hand, numerous boulders of granite have been carried to the northward from the hills of

Annapolis, and deposited on the slopes of the opposite trappean ridge; and some of them have been carried round its eastern end, and now lie on the shores of Londonderry and Onslow. So also, while immense numbers of boulders have been scattered over the south coast from the granite and quartz rock ridges immediately inland, many have drifted in the opposite direction, and may be found scattered over the counties of Sydney, Pictou, and Colchester. These facts show that the transport of travelled blocks, though it may here as in other parts of America, have been principally from the northward, has by no means been exclusively so; boulders having been carried in various directions, and more especially from the more elevated and rocky districts to the lower grounds in their vicinity. Professor Hind has shown the existence of a similar relation between the boulders of New Brunswick and the hilly ranges of that country.

As might have been expected, the removal of these travelled masses has occasioned important changes of the surface, or, to use the ordinary geological term, there has been very extensive *denudation* in the production of the boulder deposits. A very large proportion of the present features of the surface indeed result from this cause; the ridges of Cumberland, the deep valley of Cornwallis and Annapolis, the great gorges crossing the Cobequid Mountains and the western end of the North Mountains in Annapolis and Digby counties, such eminences as the Greenhill in Pictou county, and Onslow Mountain in Colchester, are due in great part to the removal of soft rocks by denuding agencies of this period, while the harder rocks remained in projecting ridges. On the other hand, it might be shown that many masses of rock which once projected above the surface have been greatly diminished or entirely removed.

One of the most remarkable effects of the transport of surface materials is the *scratching and polishing of rock surfaces*, a phenomenon which prevails very extensively over the northern parts of America and Europe, and may be frequently observed in Nova Scotia. Indeed it is the rule rather than the exception, that when a fresh rock-surface is uncovered by the removal of the boulder clay, it is found to be smoothed and marked with striæ, scratches, and furrows, usually in a uniform direction; the whole being evidently the result of the passage of heavy and hard substances over the surface. These scratches or furrows are useful as indicating the direction in which the mass of superficial detritus has been moved; and I have even used this direction with success in tracing useful minerals found in fragments among the drift to the sources whence they were derived. I give below the directions of the diluvial scratches in a number of localities in different parts of the province.

Point Pleasant, and other places near Halifax, exposure south, very distinct striæ, .	S. 20° E. to S. 30° E.
Head of the Basin, exposure south, but in a valley, ...	E. & W. nearly.
La Have River, exposure S.E., . .	S. 20° W.
Petite River, exposure S.	S. 20° E.
Bear River, exposure N., . . .	S. 30° E.
Rawdon, exposure N., ...	S. 25° E.
The Gore Mountain, exposure N., two sets of striæ, respectively, ...	S. 65° E. & S. 20° E.
Windsor Road, exposure not noted, .	S.S.E.
Gay's River, exposure N., . . .	Nearly S. & N.
Musquodoboit Harbour, exposure S., .	Nearly S. & N.
Near Pictou, exposure E., in a valley, .	Nearly E. & W.
Polson's Lake, summit of a ridge, . .	Nearly N. & S.
Near Guysboro', exposure not noted, .	Nearly S. & N.
Sydney Mines, Cape Breton, exposure S.	S. 30° W.*

The above instances show a tendency to a southerly and south-easterly direction, which accords with the prevailing course in most parts of North-eastern America. Local circumstances have, however, modified this prevailing direction; and it is interesting to observe that, while S. E. is the prevailing direction in Acadia and New England, it is exceptional in the St Lawrence valley, where the prevailing direction is S.W.† Professor Hind has given a table of similar striation in New Brunswick, showing that the direction ranges from N. 10° W. to N. 30° E., in all except a very few cases. On Blue Mountains, 1650 feet above the sea, it is stated to be N. and S. As in Nova Scotia, N. W. and S. E. seems to be the prevailing course.

The travelled and untravelled boulders are usually intermixed in the drift. In some instances, however, the former appear to be most numerous near the surface of the mass, and their horizontal distribution is also very irregular. In examining coast sections of the drift, we may find for some distance a great abundance of angular blocks, with few travelled boulders, and then we may observe a portion of the shore or bank in which both varieties are equally intermixed, or in which travelled boulders prevail; and we may often observe particular kinds of these last grouped together, as, for instance, a number of blocks of granite, greenstone, syenite, etc., all lying together, as if they had been removed from their original beds and all deposited

* The above and other courses in this volume are *magnetic*, the average variation being about 18° W.

† Logan, "Report on Geology of Canada."

ology. In reasoning, however, on this subject as regards Nova Scotia, I have the advantage of appealing to causes now in operation within the country, and which are at present admitted by the greater number of modern geological authorities to afford the best explanation of the phenomena. In the first place, it may at once be admitted that no such operations as those which formed the drift are now in progress on the surface of the land, so that the drift is a relic of a past state of things, in so far at least as regards the localities in which it now rests. In the next place, we find, on examining the drift, that it strongly resembles, though on a greater scale, the effects now produced by frost and floating ice. Frost breaks up the surface of the most solid rocks, and throws down cliffs and precipices. Floating ice annually takes up and removes immense quantities of loose stones from the shores, and deposits them in the bottom of the sea or on distant parts of the coasts. Very heavy masses are removed in this way. I have seen in the Strait of Canseau large stones, ten feet in diameter, that had been taken from below low-water mark and pushed up upon the beach. Stones so large that they had to be removed by blasting, have been taken from the base of the cliffs at the Joggins and deposited off the coal-loading pier, and I have seen resting on the mud-flats at the mouth of the Petitcodiac River a boulder at least eight feet in length, that had been floated by the ice down the river (Fig. 11). Another

Fig. 11.—*Travelled Stone, Petitcodiac River.*

testimony to the same fact is furnished by the rapidity with which huge piles of fallen rock are removed by the floating ice from the base of the trap cliffs of the Bay of Fundy. Let us suppose, then, the surface of the land, while its projecting rocks were still uncovered by surface deposits, exposed for many successive centuries to the action of alternate frosts and thaws, the whole of the untravelled drift might have been accumulated on its surface. Let it then be submerged until its hill-tops should become islands or reefs of rocks in a sea loaded in winter and spring with drift ice, floated along by currents, which, like the present Arctic current, would set from N.E. to S.W. with various modifications produced by local causes. We have in these

causes ample means for accounting for the whole of the appearances, including the travelled blocks and the scratched and polished rock-surfaces. This, however, is only a general explanation. Had we time to follow it into details, many most interesting and complicated facts and processes would be discovered. I mention merely one for an example, as it illustrates the manner in which the land may have subsided beneath the boulder-bearing seas. I have stated that large blocks of sandstone from the plains of Cumberland have been carried to the summits of the Cobequid Mountains. When these blocks were carried to their present place, the waters must have reached to the summits of the hills; but at that time the plain from which these blocks came must have been several hundred feet below the sea-level. How then could ice take them from such a depth? We may fancy huge icebergs grounding in this deep water, but they could not float over the hills or ground against their summits. The explanation is that the country was gradually subsiding. While the water was shallow, the blocks were drifted against the base of the hills. As the land sunk, the ice-fields of successive years gradually pushed them higher, until the summits of the hills were submerged so deeply that the ice could no longer take up the blocks. Most of the apparent anomalies of the drift may be explained in such ways, when the theory of ice-carriage is once admitted.

I have retained the above explanation of the boulder clay, which appeared in my edition of 1855, because I have as yet seen no reason to change my opinion on the subject, although I have since that time had opportunities of studying the Post-pliocene of Canada and other parts of America and of Europe, and have read nearly all that has been written by the advocates of a terrestrial origin of this deposit, in a supposed glacial period when the whole of the northern parts of Europe and America are imagined to have been covered with glaciers, or rather with a universal glacier like that of Greenland, but on an enormously larger scale. The more I have considered this hypothesis, the more improbable it has appeared, whether in a mechanical, meteorological, or geological point of view; and a recent visit to Mont Blanc, and the study of the effects produced by icebergs in the Straits of Belleisle, have more fully established in my mind the belief that floating ice and the Arctic current have been the grand agents employed. As the glacier hypothesis of Agassiz, Ramsay, and others, has been incorporated into the best American text-book of geology, that of Professor Dana, and has recently been ably advocated in the case of New Brunswick, I may here give some of my reasons for dissenting from it, as stated in a paper published some time ago in Canada.

The facts to be accounted for are the striation and polishing of rock surfaces, the deposit of a sheet of unstratified clay and stones, the transport of boulders from distant sites lying to the northward, and the deposit on the boulder clay of beds of stratified clay and sand, containing marine shells. The rival theories in discussion are,—*first*, that which supposes a gradual subsidence and re-elevation, with the action of the sea and its currents, bearing ice at certain seasons of the year; and, *secondly*, that which supposes the American land to have been covered with a sheet of glacier several thousands of feet thick.

The last of these theories, without attempting to undervalue its application to such regions as those of the Alps or of Spitzbergen or Greenland, has appeared to me inapplicable to the drift deposits of eastern America, for the following among other reasons:—

1. It requires a series of suppositions unlikely in themselves and not warranted by facts. The most important of these is the coincidence of a wide-spread continent and a universal covering of ice in a temperate latitude. In the existing state of the world, it is well known that the ordinary conditions required by glaciers in temperate latitudes are elevated chains and peaks extending above the snow-line; and that cases in which, in such latitudes, glaciers extend nearly to the sea-level, occur only where the mean temperature is reduced by cold ocean-currents approaching to high land, as for instance in Tierra del Fuego and the southern extremity of South America. But the temperate regions of North America could not be covered with a permanent mantle of ice under the existing conditions of solar radiation; for, even if the whole were elevated into a table-land, its breadth would secure a sufficient summer heat to melt away the ice, except from high mountain-peaks. Either, then, there must have been immense mountain-chains which have disappeared, or there must have been some unexampled astronomical cause of refrigeration, as, for example, the earth passing into a colder portion of space, or the amount of solar heat being diminished. But the former supposition has no warrant from geology, and astronomy affords no evidence for the latter view, which, besides, would imply a diminution of evaporation militating as much against the glacier theory as would an excess of heat. An attempt has recently been made by Professor Frankland to account for such a state of things by the supposition of a higher temperature of the sea, along with a colder temperature of the land; but this inversion of the usual state of things is unwarranted by the doctrine of the secular cooling of the earth; it is contradicted by the fossils of the period, which show that the seas were colder than at present; and if it existed, it could not produce the effects required, unless a

preternatural arrest were at the same time laid on the winds, which spread the temperature of the sea over the land. The alleged facts observed in Norway, and stated to support this view, are evidently nothing but the results ordinarily observed in ranges of hills, one side of which fronts cold sea-water, and the other land warmed in summer by the sun.

The supposed effects of the varying eccentricity of the earth's orbit, so ably expounded by Mr Croll, are no doubt deserving of consideration in this connexion; but I agree with Sir Charles Lyell in regarding them as insufficient to produce any effect so great as that refrigeration supposed by the theory now before us, even if aided by what Sir Charles truly regards as a more important cause of cold,—namely, a different distribution of land and water, in such a manner as to give a great excess of land in high latitudes.

2. It seems physically impossible that a sheet of ice, such as that supposed, could move over an uneven surface, striating it in directions uniform over vast areas, and often different from the present inclinations of the surface. Glacier ice may move on very slight slopes, but it must follow these; and the only result of the immense accumulation of ice supposed, would be to prevent motion altogether by the want of slope or the counteraction of opposing slopes, or to induce a slight and irregular motion toward the margins or outward from the more prominent protuberances.

It is to be observed, also, that, as Hopkins has shown, it is only the *sliding* motion of glaciers that can polish or erode surfaces, and that any internal changes resulting from the mere weight of a thick mass of ice resting on a level surface, could have little or no influence in this way.

3. The transport of boulders to great distances, and the lodgment of them on hill-tops, could not have been occasioned by glaciers. These carry downward the blocks that fall on them from wasting cliffs. But the universal glacier supposed could have no such cliffs from which to collect; and it must have carried boulders for hundreds of miles, and left them on points as high as those they were taken from. On the Montreal Mountain, at a height of 600 feet above the sea, are huge boulders of feldspar from the Laurentide Hills, which must have been carried 50 to 100 miles from points of scarcely greater elevation, and over a valley in which the striæ are in a direction nearly at right angles with that of the probable driftage of the boulders. Quite as striking examples occur in many parts of this country. It is also to be observed that boulders, often of large size, occur scattered through the marine stratified clays and sands containing sea-shells;

and whatever views may be entertained as to other boulders, it cannot be denied that these have been borne by floating ice. Nor is it true, as has been often affirmed, that the boulder clay is destitute of marine fossils. At Isle Verte, Riviere du Loup, Murray Bay, and St Nicholas on the St Lawrence, and also at Cape Elizabeth, near Portland, there are tough stony clays of the nature of true "till," and in the lower part of the drift, which contain numerous marine shells of the usual Post-pliocene species.

4. The Post-pliocene deposits of Canada, in their fossil remains and general character, indicate a gradual elevation from a state of depression, which on the evidence of fossils must have extended to at least 500 feet, and on that of far-travelled boulders to several times that amount; while there is nothing but the boulder clay to represent the previous subsidence, and nothing whatever to represent the supposed previous ice-clad state of the land, except the scratches on the rock surfaces, which must have been caused by the same agency which deposited the boulder clay.

5. The peat deposits, with fir-roots, found below the boulder clay in Cape Breton, the remains of plants and land-snails in the marine clays of the Ottawa, and the shells of the St Lawrence clays and sands, show that the sea at the period in question had nearly the temperature of the present Arctic currents of our coasts, and that the land was not covered with ice, but supported a vegetation similar to that of Labrador and the north shore of the St Lawrence at present. This evidence refers not to the later period of the Mammoth and Mastodon, when the re-elevation was perhaps nearly complete, but to the earlier period contemporaneous with or immediately following the supposed glacier period. In my former papers on the Post-pliocene of the St Lawrence, I have shown that the change of climate involved is not greater than that which may have been due to the subsidence of land, and to the change of course of the Arctic current, actually proved by the deposits themselves.

These objections might be pursued to much greater length; but enough has been said to show that there are, in the case of north-eastern America, strong reasons against the existence of any such period of extreme glaciation as supposed by many geologists; and that if we can otherwise explain the rock striation and polishing, and the formation of fiords and lake basins, the strong points with these theorists, we can dispense altogether with the portentous changes in physical geography involved in their views, and which are not necessary to explain any of the other phenomena.

On these points, the Report of the Geological Survey of Canada

throws new light; though Sir William Logan, with his usual caution, has not committed himself to theoretical conclusions; and in one or two local cases he seems to favour the glacier theory. It has long been known to geologists, that in north-eastern America, two main directions of striation of rock surfaces occur, from north-east to south-west, and from north-west to south-east; and that locally the directions vary from these to north and south and east and west. Various attempts have been made, but without much success, to account for these directions of striation by the motion of glaciers; and while it is quite easy for any one prepossessed with this view to account in this way for the striation in a particular valley or part of a valley, yet so many exceptional facts occur as to throw doubt on the explanation, except in the case of a few of the smaller and steeper mountain gorges.

In the Report of the Survey of Canada a valuable table of these striations is given, from which it appears that they are locally distributed in such a way as to throw a decided gleam of light on their origin.

It would seem that the dominant direction in the valley of the St Lawrence, along the high lands to the north of it, and across western New York, is north-east and south-west; and that there is another series of scratches running nearly at right angles to the former, across the neck of land between Georgian Bay and Lake Ontario, down the valley of the Ottawa, and across parts of the Eastern Townships, connecting with the prevalent south and south-east striation which occurs in the valleys of the Connecticut and Lake Champlain, and elsewhere in New England, as well as in Nova Scotia and New Brunswick. What were the determining conditions of these two courses, and were they contemporaneous or distinct in time? The first point to be settled in answering these questions is the direction of the force which caused the striæ. Now, I have no hesitation in asserting, from my own observations as well as from those of others, that for the south-west striation the direction was *from the ocean toward the interior, against the slope of the St Lawrence valley*. The crag-and-tail forms of all our isolated hills, and the direction of transport of boulders carried from them, show that throughout Canada the movement was from north-east to south-west.* This at once disposes of the glacier-theory for the prevailing set of striæ; for we cannot suppose a glacier moving from the Atlantic up into the interior. On the other hand, it is eminently favourable to the idea of ocean drift. A subsidence of

* The few exceptional cases appear to belong mostly to the later period of the stratified sands.

America, such as would at present convert all the plains of Canada and New York and New England into sea, would determine the course of the Arctic current over this submerged land from north-east to south-west; and as the current would move *up a slope*, the ice which it bore would tend to ground, and to grind the bottom as it passed into shallower water; for it must be observed that the character of slope which enables a glacier to grind the surface may prevent ice borne by a current from doing so, and *vice versa.*

Now we know that in the Post-pliocene period eastern America was submerged, and consequently the striation at once comes into harmony with other geological facts. We have, of course, to suppose that the striation took place during submergence, and that the process was slow and gradual, beginning near the sea and at the lower levels, and carried upwards to the higher grounds in successive centuries, while the portions previously striated were covered with deposits swept down from the sinking land or dropped from melting ice. It would be easy to show that this view corresponds with many of the minor facts.

Farther, the theory thus stated accounts for the excavation of the deep and land-locked basins of our great American lakes. Ocean currents, if cold, and clinging to the bottom, must cut out pot-holes, just as rivers do, though geologists are too apt to limit their function to the throwing up of banks. The course of the present Arctic current along the American coast has its deep hollows as well as its sand-banks. Our American lake-basins are cut out deeply into the softer strata. Running water on the land would not have done this, for it could have no outlet; nor could this result be effected by breakers. Glaciers could not have effected it; for even if the climatal conditions for these were admitted, there is no height of land to give them momentum. But if we suppose the land submerged so that the Arctic current, flowing from the north-east, should pour over the Laurentian rocks on the north side of Lake Superior and Lake Huron, it would necessarily cut out of the softer Silurian strata just such basins, drifting their materials to the south-west. At the same time, the lower strata of the current would be powerfully determined through the strait between the Adirondac and Laurentide Hills, and, flowing over the ridge of hard rock which connects them at the Thousand Islands, would cut out the long basin of Lake Ontario, heaping up at the same time, in the lee of the Laurentian ridge, the great mass of boulder clay which intervenes between Lake Ontario and Georgian Bay. Lake Erie may have been cut by the flow of the upper layers of water over the Middle Silurian escarpment; and Lake Michigan, though

less closely connected with the direction of the current, is, like the others, due to the action of a continuous eroding force on rocks of unequal hardness.

The predominant south-west striation, and the cutting of the upper lakes, demand an outlet to the west for the Arctic current. But both during depression and elevation of the land, there must have been a time when this outlet was obstructed, and when the lower levels of New York, New England, and Canada were still under water. Then the valley of the Ottawa, that of the Mohawk, and the low country between Lakes Ontario and Huron, and the valleys of Lake Champlain and the Connecticut, would be straits or arms of the sea, and the current, obstructed in its direct flow, would set principally along these, and act on the rocks in north and south and north-west and south-east directions. To this portion of the process I would attribute the north-west and south-east striation. It is true that this view does not account for the south-east striæ observed on some high peaks in New England; but it must be observed that even at the time of greatest depression, the Arctic current would cling to the northern land, or be thrown so rapidly to the west that its direct action might not reach such summits.

Nor would I exclude altogether the action of glaciers in eastern America, though I must dissent from any view which would assign to them the principal agency in our glacial phenomena. Under a condition of the continent in which only its higher peaks were above the water, the air would be so moist, and the temperature so low, that permanent ice may have clung about mountains in the temperate latitudes. The striation itself shows that there must have been extensive glaciers, as now, in the extreme Arctic regions. Yet I think that most of the alleged instances must be founded on error, and that old sea-beaches have been mistaken for moraines. I have failed to find even in our higher mountains any distinct sign of glacier action, though the action of the ocean-breakers is visible almost to their summits; and though I have observed in Canada and Nova Scotia many old sea-beaches, gravel-ridges, and lake-margins, I have seen nothing that could fairly be regarded as the work of glaciers. The so-called moraines, in so far as my observation extends, are more probably shingle beaches and bars, old coast-lines loaded with boulders, trains of boulders or "ozars." Most of them convey to my mind the impression of ice-action along a slowly subsiding coast, forming successive deposits of stones in the shallow water, and burying them in clay and smaller stones as the depth increased. These deposits were again modified during emer-

gence, when the old ridges were sometimes bared by denudation, and new ones heaped up.*

I shall close these remarks, perhaps already too tedious, by a mere reference to the alleged prevalence of lake basins and fiords in high northern latitudes, as connected with glacial action. In reasoning on this, it seems to be overlooked that the prevalence of hard metamorphic rocks over wide areas in the north is one element in the matter. Again, cold Arctic currents are the cutters of basins, not the warm surface-currents. Further, the fiords on coasts like the deep lateral valleys of mountains are evidences of the action of the waves and currents rather than of that of ice. I am sure that this is the case with the numerous indentations of the coast of Nova Scotia, which are cut into the softer and more shattered bands of rock; and show, in raised beaches and gravel ridges like those of the present coast, the levels of the sea at the time of their formation.

In Nova Scotia we have the means of applying another and crucial test to this theory of lake basins. The whole surface of the peninsula has been striated and polished; and it has been estimated that one-third of its area is occupied by lakes, most of them of small dimension. Now these lakes are almost entirely confined to those metamorphic regions where unequal hardness and imperfect facilities for drainage tend to promote their occurrence. It is evident, therefore, that we are to seek for the origin of the lake basins in these local causes, and not in any universal covering of glacier. Further, as I have above shown, the manner in which the great Canadian lakes have been cut out of the softer materials, and their relations to the neighbouring harder portions of the country, prove that these great basins may be due to the action of ocean-currents, a cause to which I would attribute also the greater part of the smaller lakes of Nova Scotia. To these reasons I may add the following comparative statements of the effects of glaciers and icebergs, deduced from examinations of the glaciers of Mont Blanc and the icebergs of Belleisle:—†

* I have no doubt that Logan, Hind, and Packard, are correct in assigning some of the striation in the Laurentide Hills of Canada and Labrador to glaciers. The valley of the Saguenay, which is a deep cut caused by denudation along a line of fracture traversing the Laurentian rocks, shows near its mouth distinct "roches moutonnees" smoothed on the northern side, and very deep grooves and striæ cut in hard gneiss with a direction of S. 10 E. magnetic, which is nearly at right angles to the ordinary striation of the St Lawrence valley. I think it quite possible that these appearances may have been caused by a local glacier, and if so, there may have been glaciers along the whole line of the Laurentide Hills, with their extremities reaching to the sea or strait then filling the St Lawrence valley.

† Comparisons of the Icebergs of Belleisle and the Glaciers of Mont Blanc, Canadian Naturalist, 1867.

1. Glaciers heap up their debris in abrupt ridges. Floating ice sometimes does this, but more usually spreads its load in a more or less uniform sheet.

2. The material of moraines is all local. Icebergs carry their deposits often to great distances from their sources.

3. The stones carried by glaciers are mostly angular, except where they have been acted on by torrents. Those moved by floating ice are more often rounded, being acted on by the waves and by the abrading action of sand drifted by currents.

4. In the marine glacial deposits mud is mixed with stones and boulders. In the case of land glaciers most of this mud is carried off by streams and deposited elsewhere.

5. The deposits of floating ice may contain marine shells. Those of glaciers cannot, except where, as in Greenland and Spitzbergen, glaciers push their moraines out into the sea.

6. It is of the nature of glaciers to flow in the deepest ravines they can find, and such ravines drain the ice of extensive areas of mountain land. Icebergs, on the contrary, act with greatest ease on flat surfaces or slight elevations in the sea bottom.

7. Glaciers must descend slopes and must be backed by large supplies of perennial snow. Icebergs act independently, and, being water-borne, may work up slopes and on level surfaces.

8. Glaciers striate the sides and bottoms of their ravines very unequally, acting with great force and effect only on those places where their weight impinges most heavily. Icebergs, on the contrary, being carried by constant currents and over comparatively flat surfaces, must striate and grind more regularly over large areas, and with less reference to local inequalities of surface.

9. The direction of the striæ and grooves produced by glaciers depends on the direction of valleys. That of icebergs, on the contrary, depends upon the direction of marine currents, which is not determined by the outline of the surface, but is influenced by the large and wide depressions of the sea-bottom.

10. When subsidence of the land is in progress, floating ice may carry boulders from lower to higher levels. Glaciers cannot do this under any circumstances, though in their progress they may leave blocks perched on the tops of peaks and ridges.

The only portion of Acadia in which stratified clays holding marine shells have been found overlying the boulder clay, or in connexion with it, is in the southern part of New Brunswick, where deposits of this kind occur similar to those found in Canada and in Maine, though apparently on a smaller scale. These deposits, as they occur near St

Fossils of the Post-pliocene (from Canadian specimens).

Fig. 12.

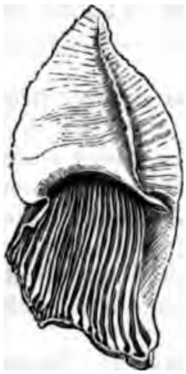


Fig. 13.

Fig. 14.

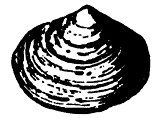


Fig. 15.

Fig. 12 *a*.

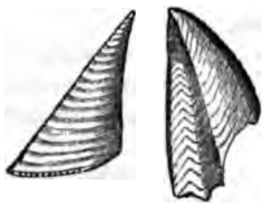


Fig. 16.

Fig. 17.

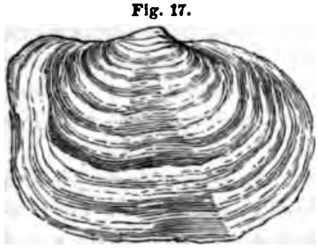


Fig. 18.

Fig. 19.

Fig. 20.

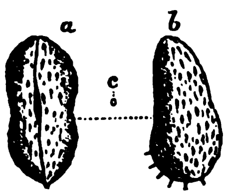


Fig. 21.

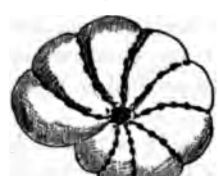


Fig. 12. Balanus Hameri, (*a*) opercula. **Fig. 13.** Mytilus edulis. **Fig. 14.** Tellina Grœnlandica.
„ 15. Saxicava rugosa. „ 16. Tellina calcarea. „ 17. Mya truncata.
„ 18. Natica clausa. „ 19. Buccinum undatum, var.
„ 20. Cytheridea Mulleri, (*c*) nat. size. **Fig. 21.** Polystomella striatopunctata, mag.

John, consist of gray and reddish clays, holding fossils which indicate moderately deep water, and are, as to species, identical with those occurring in similar deposits in Canada and in Maine. They would indicate a somewhat lower temperature than that of the waters of the Bay of Fundy at present, or about that of the northern part of the Gulf of St Lawrence. They correspond to the Leda clay of Canada and Maine.

Mr C. F. Hartt has given, in Prof. Bailey's Report on New Brunswick, the following list of fossils from these beds. I have affixed an asterisk to the species found also in the Leda clay and Saxicava sand of Canada.

Articulata.

Balanus Hameri,* *Asc.*, Lawlor's Lake.
B. crenatus,* " "

Mollusca.

Pecten islandicus,* *Linn.*, Lawlor's Lake, R. R. Depot, Saint John.
P. tenuistriatus, Migh., " "
Mytilus edulis, *Linn.** " " " "
Cardium pinnulatum, *Con.* " " "
Tellina Grœnlandica* (= T. Balthica *Linn.*), Lawlor's Lake, etc.
T. calcarea* (= Macorna sabulosa, *Stp.*), Duck Cove, etc.
Leda Jacksoni (= L. pernula*), Lawlor's Lake.
L. truncata,* Duck Cove; Lawlor's Lake; R. R. Depot, Saint John.
Nucula antiqua (var. of N. tenuis.),* " " "
Mya arenaria.* " " "
M. truncata,*
Aphrodite (Serripes) Grœnlandica, *Beck*, Duck Cove, etc.
Cardium islandicum,* *Linn.*
Mesodesma, R. R. Depot.
Saxicava distorta, *Say.* (= S. rugosa, *Linn.*)*
Lyonsia arenosa, Duck Cove.*
Lacuna neritoidea,* *Gould*, Duck Cove.
Pandora trilineata, "
Natica clausa, *Sow*,* "
Buccinum undatum,* *Linn*, Duck Cove.

Bryozoa, several species undetermined, Taylor's Island, Lawlor's Lake, etc.

Radiata.

Ophioglypha Sarsii, *Lutk.*, Saint John, Duck Cove.*
Toxopneustes drobachiensis (Echinus granulatus, *Say.*),* Red Head, Lawlor's Lake.

Plants.—Algæ, three species, undetermined.—Manawagonis.

In some specimens sent to me by Mr Matthew, I find, in addition to the forms above enumerated, some microscopic organisms, more especially *Polystomella striatopunctata* (*umbilicata* of Walker), and several species of *Cythere;* and among the Bryozoa I recognise *Pustulipora*, *Tubulipora serpens* and *Crisia eburnea*, all in small fragments.

In the absence of fossils, the drift of Nova Scotia contrasts strongly with the Post-pliocene clays and sands of the lower St Lawrence and the St John. These deposits abound in marine shells, and mark the stages of recession of the sea as the American land rose from the great depression of the period of the boulder formation, in which nearly the whole continent was submerged. The absence of the fossiliferous marine clays in Nova Scotia may indicate a more rapid elevation of the land, not giving time for permanent sea-bottoms; or, on the other hand, a slow rise accompanied by very great denudation. The position of Nova Scotia and the aspect of its boulder clay point rather to the latter conclusion. In this case, remnants may exist; and, judging from appearances in Canada, Maine, and New Brunswick, I should suppose that marine remains are most likely to be found at the junction of the boulder clay with the overlying stratified drift, and in places sheltered by hills or ledges of rock. From papers on this subject, relating more especially to Canada, I may select the following statements as important to the geology of these formations in Acadia as well:—*

The arrangement of the Post-pliocene deposits at Logan's Farm near Montreal, and Beauport near Quebec, confirms the subdivision, which I have attempted to establish, of these beds into an underlying unstratified boulder clay, a deep-water bed of clay or sand (the "Leda clay" of Montreal), and, overlying shallow-water sands and gravels (the "Saxicava sand"). This arrangement shows a gradual upheaval of the land from its state of depression in the boulder clay period, corresponding with what has been deduced from similar appearances in the Old World. "The upheaval of the bed of the glacial sea," says Forbes, "was not sudden but gradual. The phenomena so well described by Professor Forchammer in his essays on the Danish drift, indicating the conversion of a muddy sea of some depth into one choked up with sand-banks, are, though not universal, equally evident in the British Isles, especially in Ireland and the Isle of Man."†

We now have in all, exclusive of doubtful forms, about one hundred species of marine invertebrates from the Post-pliocene clays of the St Lawrence valley. All, except four or five species belonging

* Canadian Naturalist and Geologist, vols. ii., iii., and iv.

† Memoirs of Geological Survey.

to the older or deep-water part of the deposit, are known as living shells of the Arctic or boreal regions of the Atlantic. About half of the species are fossil in the Post-pliocene of Great Britain. The great majority are now living in the Gulf of St Lawrence and on the neighbouring coasts; and more especially on the north side of the gulf and the coast of Labrador. In so far, then, as marine life is concerned, the modern period in this country is connected with that of the boulder clay by an unbroken chain of animal existence. These deposits in Lower Canada afford no indications of the terrestrial fauna; but the remains of *Elephas primigenius* in beds of similar age in Upper Canada,* show that during the period in question great changes occurred among the animals of the land; and we may hope to find similar evidences elsewhere, especially in localities where, as on the Ottawa, the debris of land-plants and land-shells occur in the marine deposits.

The climate of this period, as indicated by its marine animals, and the causes of its difference from that which now obtains in the northern hemisphere, have been fertile subjects of discussions and controversies, which I have no wish here to reopen. I desire, however, to state, in a manner level to the comprehension of the ordinary reader, the facts of the case in so far as relates to Canada, and equally to the maritime provinces, and an important inference to which they appear to me to lead, and which, if sustained, will very much simplify our views of this question.

Every one knows that the means and extremes of annual temperature differ much on the opposite sides of the Atlantic. The isothermal line of 40°, for example, passes from the south side of the Gulf of St Lawrence, skirts Iceland, and reaches Europe near Drontheim in Norway. This fact, apparent as the result of observations on the temperature of the land, is equally evidenced by the inhabitants and physical phenomena of the sea. A large proportion of the shell-fish inhabiting the Gulf of St Lawrence and the coast thence to Cape Cod occur on both sides of the Atlantic, but not in the same latitudes. The marine fauna of Cape Cod is parallel, in its prevalence of boreal forms, with that of the south of Norway. In like manner, the descent of icebergs from the north, the freezing of bays and estuaries, the drifting and pushing of stones and boulders by ice, are witnessed on the American coast in a manner not paralleled in corresponding latitudes in Europe. It follows from this, that a collection of shells from any given latitude on the coasts of Europe or America would bear testimony to the existing difference of climate. The geologist

* Reports of Geol. Survey; Lyell's Travels.

appeals to the same kind of evidence with reference to the climate of the Post-tertiary period, and let us inquire what is its testimony.

The first and most general answer usually given is, that the Post-pliocene climate was colder than the Modern. The proof of this in Western Europe is very strong. The marine fossils of this period in Britain are more like the existing fauna of Norway or of Labrador than the present fauna of Britain. Great evidences exist of driftage of boulders by ice, and traces of glaciers on the higher hills. In North America the proofs of a rigorous climate, and especially of the transport of boulders and other materials by ice, are equally good, and the marine fauna all over Canada and New England is of boreal type. In evidence of these facts, I may appeal to the papers and other publications of Sir C. Lyell and Professor Ramsay on the formations of the so-called Glacial period in Europe and America,* and to my own previous papers on the Post-tertiary of Canada.

Admitting, however, that a rigorous climate prevailed in the Post-pliocene period, it by no means follows that the change has been equally great in different localities. On the contrary, while a great and marked revolution has occurred in Europe, the evidences of such change are very much more slight in America. In short, the causes of the coldness of the Post-pliocene seas to some extent still remain in America, while they must have disappeared or been modified in Europe.

If we inquire as to these causes as at present existing, we find them in the distribution of ocean-currents, and especially in the great warm current of the Gulf Stream thrown across from America to Europe, and in the Arctic currents bathing the coasts of America. In connexion with these we have the prevailing westerly winds of the temperate zone, and the great extent of land and shallow seas in northern America. Some of these causes are absolutely constant. Of this kind is the distribution of the winds, depending on the earth's temperature and rotation. The courses of the currents are also constant, except in so far as modified by coasts and banks; and the direction of the drift-scratches and transport of boulders in the Post-pliocene both of Europe and America show that the Arctic currents at least have remained unchanged. But the distribution of land and water is a variable element, since we know that in the period in question nearly all northern Europe, Asia and America, were at one time or another under the waters of the sea; and it is consequently to

* Lyell's Travels in North America; Ramsay on the Glaciers of Wales, and on the Glacial Phenomena of Canada. See also Forbes on the Fauna and Flora of the British Islands, in Memoirs of Geological Survey.

this cause that we must mainly look for the changes which have occurred.

Such changes of level must, as has been long since shown by Sir Charles Lyell, modify and change climate. Every diminution of the land in Arctic America must tend to render its climate less severe. Every diminution of land in the temperate regions must tend to reduce the mean temperature. Every diminution of land anywhere must tend to diminish the extremes of annual temperature; and the condition of the southern hemisphere at present shows that the disappearance of the great continental masses under the water would lower the mean temperature, but render the climate much less extreme. Glaciers might then exist in latitudes where now the summer heat would suffice to melt them—as Darwin has shown that in South America glaciers extend to the sea level in latitude 46° 50′,—and at the same time the ice would melt more slowly and be drifted farther to the southward. Any change that tended to divert the Arctic currents from our coasts would raise the temperature of their waters. Any change that would allow the equatorial current to pursue its course through to the Pacific, or along the great inland valley of North America, would reduce the British seas to a boreal condition.

The boulder formation and its overlying fossiliferous beds prove, as I have in a previous paper endeavoured to explain with regard to Canada, and as has been shown by other geologists in the case of other parts of America and of Europe, that the land of the northern hemisphere underwent in the Post-tertiary period a great and gradual depression and then an equally gradual elevation. Every step of this process would bring its modifications of climate, and when the depression had attained its maximum there probably was as little land in the temperate regions of the northern hemisphere as in the southern now. This would give a low mean temperature and an extension to the south of glaciers, more especially if, at the same time, a considerable Arctic continent remained above the waters, as seems to be indicated by the effects of extreme marine glacial action on the rocks under the boulder clay. These conditions, actually indicated by the phenomena themselves, appear quite sufficient to account for the coldness of the seas of the period; and the wide diffusion of the Gulf Stream caused by the subsidence of American land, or its entire diversion into the Pacific basin,* would give that assimilation of the

* This is often excluded from consideration, owing to the fact that the marine fauna of the Gulf of Mexico differs almost entirely from that of the Pacific coast; but the question still remains, whether this difference existed in the Later Tertiary period, or has been established in the Modern epoch, as a consequence of changed physical conditions.

American and European climates so characteristic of the time. The climate of western Europe, in short, would, under such a state of things, be greatly reduced in mean temperature: the climate of America would suffer a smaller reduction of its mean temperature, but would be much less extreme than at present; the general effect being the establishment of a more equable but lower temperature throughout the northern hemisphere. It is perhaps necessary to add, that the existence on the land, during this period of depression, of large elephantine mammals in northern latitudes, as, for instance, the mammoth and mastodon, does not contradict this conclusion. We know that these creatures were clothed in a manner to fit them for a cool climate, and an equable rather than a high temperature was probably most conducive to their welfare, while the more extreme climate consequent on the present elevation and distribution of the land may have led to their extinction.

The establishment of the present distribution of land and water, giving to America its extreme climate, leaving its seas cool, and throwing on the coasts of Europe the heated water of the tropics, would thus affect but slightly the marine life of the American coast, but very materially that of Europe, producing the result already referred to in the above pages, that the Canadian Post-pliocene fauna differs comparatively little from that now existing in the Gulf of St Lawrence; though in so far as any difference subsists, it is in the direction of an Arctic character. The changes that have occurred were perhaps all the less that so soon as the Laurentide Hills to the north of the St Lawrence valley emerged from the sea, the coasts to the south of these hills would be effectually protected from the heavy northern ice-drifts and from the Arctic currents, and would have the benefit of the full action of the summer heat,—advantages which must have existed to a less extent in western Europe.

It is farther to be observed, that such subsidence and elevation would necessarily afford great facilities for the migration of Arctic marine animals, and that the difference between the Modern and Post-pliocene faunas must be greatest in those localities to which the forms of temperate regions could most readily migrate after the change of temperature had occurred.

It has been fully shown by many previous writers on this subject, that the causes above referred to are sufficient to account for all the local and minor phenomena of the stratified and unstratified drifts, and for the driftage of boulders and other materials, and the erosion that accompanied its deposition. Into these subjects I do not propose to enter; my object in these remarks being merely to give the reasons

for my belief stated in previous papers on this subject, that the difference of climate between Post-pliocene and Modern America, and the less amount of that difference relatively to that which has occurred in western Europe, may be explained by a consideration of the changes of level which the structure and distribution of the boulder clay and the overlying fossiliferous beds prove to have occurred.

The stratified sand and gravel of Nova Scotia rests upon and is newer than the unstratified drift, and is probably also newer than the stratified marine clays above referred to. Its age is probably that of the Saxicava sand. The former relation may often be seen in coast sections or river banks, and occasionally in road-cuttings. I observed some years ago an instructive illustration of this fact, in a bank on the shore a little to the eastward of Merigomish harbour (Fig. 22). At this place the lower part of the bank consists of clay and sand with angular stones, principally sandstones. Upon

Fig. 22.—*Stratified Gravel resting on Drift,—Merigomish.*

this rests a bed of fine sand and small rounded gravel with layers of coarser pebbles. The gravel is separated from the drift below by a layer of the same sort of angular stones that appear in the drift, showing that the currents which deposited the upper bed have washed away some of the finer portions of the drift before the sand and gravel were thrown down. In this section, as well as in most others that I have examined, the lower part of the stratified gravel is finer than the upper part, and contains more sand.

In some cases we can trace the pebbles of the gravels to ancient conglomerate rocks which have furnished them by their decay; but in other instances the pebbles may have been rounded by the waters that deposited them in their present place. In places, however, where old pebble rocks do not occur, we sometimes find, instead of gravel, beds of fine laminated sand. A very remarkable instance of the connexion of superficial gravels with ancient pebble rocks cocurs in the county of Pictou. In the coal formation of this county there occurs a very thick bed of conglomerate, the outcrop of which, owing to its

comparative hardness and great mass, forms a high ridge extending from the hill behind New Glasgow across the East and Middle Rivers, and along the south side of the West River, and then, crossing the West River, re-appears in Roger's Hill. The valleys of these three rivers have been cut through this bed, and the material thus removed has been heaped up in hillocks and beds of gravel, along the banks of the streams, on the side toward which the water now flows, which happens to be the north and north-east. Accordingly, along the course of the Albion Mines Railway and the lower parts of the Middle and West Rivers, these gravel beds are everywhere exposed in the road-cuttings, and may in some places be seen to rest on the boulder clay, showing that the cutting of these valleys was completed after the drift was produced. Similar instances of the connexion of gravel with conglomerate occur near Antigonish, and on the sides of the Cobequid Mountains, where some of the valleys have at their southern entrances immense tongues of gravel extending out into the plain, as if currents of enormous volume had swept through them from north to south.

The stratified gravels do not, like the older drift, form a continuous sheet spreading over the surface. They occur in mounds and long ridges, sometimes extending for miles over the country. One of the most remarkable of these ridges is the "Boar's Back," which runs along the west side of the Hebert River in Cumberland. It is a narrow ridge, perhaps from ten to twenty feet in height, and cut across in several places by the channels of small brooks. The ground on either side appears low and flat. For eight miles it forms a natural road, rough indeed, but practicable, with care, to a carriage, the general direction being nearly north and south. What its extent or course may be beyond the points where the road enters on and leaves it, I do not know; but it appears to extend from the base of the Cobequid Mountains to a ridge of sandstone that crosses the lower part of the Hebert River. It consists of gravel and sand, whether stratified or not I could not ascertain, with a few large boulder-stones. Another very singular ridge of this kind is that running along the west side of Clyde River in Shelburne county. This ridge is higher than that on Hebert River, but, like it, extends parallel to the river, and forms a natural road, improved by art in such a manner as to be a very tolerable highway. Along a great part of its course it is separated from the river by a low alluvial flat, and on the land side a swamp intervenes between it and the higher ground. These may serve as illustrations of the "boars' backs" or "horse backs" and gravel ridges which occur in many other places, and are sometimes accom-

panied, particularly where they are crossed by gullies, by circular and oval mounds, as regular as if thrown up artificially.

Just as we attribute the formation of the older or boulder drift to the action of water and ice, while the land was subsiding beneath a frozen sea, so we may assign as the cause of the superficial gravels the action of these same waters while the country was being elevated above their level. Many of the mounds of gravel have evidently been formed by currents of water rushing through and scooping out the present valleys. Some of the more regular ridges are apparently of the nature of the gravel beaches which are thrown by the sea across the mouths of bays and coves, and may mark the continuance of the sea-level unchanged for some time in the progress of elevation. Others may have been pressed up by the edges of sheets of ice, in the manner of the ridges along the borders of our present lakes. That the action of ice in some form had not ceased, we have evidence in the large boulders sometimes found on the summits of the gravel ridges.

In the island of Cape Breton the bones of a large elephantine quadruped, evidently a species of Mastodon, have been found in connexion with the superficial gravel. This gigantic creature probably inhabited our country at the close of the Glacial or Drift period, and may have been contemporary with some of the present animals, though probably extinct before the introduction of the human race. The existence of this huge quadruped does not imply a tropical or even very warm climate, since in a skeleton found in Warren county, New Jersey, fragments of twigs, lying in such a position as to show that they had formed part of the food of the creature, were found by microscopic examination to have belonged to a species of cypress, probably the common white cedar of America; so that the animal probably browsed as the moose does at present, and could live in any wooded region.* One specimen found in the state of New York measured twenty-five feet in length and twelve feet in height. In Nova Scotia the animal must have attained to similar dimensions, for a thigh-bone, now in the museum of the Mechanics' Institute in Halifax, though apparently somewhat worn, measures three feet eleven inches in length. This huge bone and some fragments of a tusk, were the only remains of this animal that I had seen before the publication of the first edition of this work. A molar tooth has since been found in Cape Breton by Dr Honeyman, and I am now enabled by his kind assistance to figure the thigh-bone and tooth from photographs (Figs. 23 and 24). The species appears to be the *Mastodon giganteus.*

* Lyell, "Manual of Geology."

Fig. 23.—*Femur of Mastodon (reduced).*

Fig. 24.—*Molar of Mastodon (reduced).*

In conclusion of this part of the subject, we may view the Drift period as the close of the great Tertiary era of geologists. In that era there was much dry land in the northern hemisphere, and multitudes of large animals now extinct inhabited it, apparently under a climate milder than at present. Great changes, however, took place in the relative positions of land and water, inducing very important changes of climate, which finally became of an almost Arctic character over all the present temperate regions. The greater part of northern Europe and Asia appear to have subsided beneath the waters of the boulder-bearing semi-arctic ocean, until raised again by successive stages to be the abode of man and the animals of the modern earth. This final elevation, marked by the superficial gravels, appears to have fixed the present contour of the country, though the extinction of the mastodon and the phenomena of submerged forests show that important changes both in inorganic and organic nature have occurred subsequently. We have thus, in tracing back the geological history of Acadia observed first, certain modern formations now in progress, and depending wholly on the present condition of the country. We have seen in connexion with these,

evidences of subsidence of the land over an extensive area in the Modern period. A little farther back, we have observed remains showing that formerly a large elephantine quadruped now extinct inhabited the country, which we find had at a time still more ancient emerged from the bosom of the deep, under which it had long remained, while icebergs and floes were drifting masses of rock over its surface, and scraping and polishing its hills. Lastly, we have found that at a still earlier period it must have been dry land, exposed to the influence of a cold climate, and having in places peat bogs on its surface. This whole history, however, reaches no farther back than the close of the Tertiary period; and by referring to the Table in Chapter II. it will be observed, that between this period and the formation next to be described a great blank occurs, occupied in some other countries by some of the most wonderful monuments of the earth's history.

Note.—Since writing the above, I have received a very valuable memoir on the Glacial Phenomena of Labrador and Maine, by A. S. Packard, M.D. The author, though attaching more importance to the action of glaciers than I am disposed to admit, states many important facts and conclusions bearing on the subject of this chapter. Adopting the term "Syrtensian" for the marine fauna of Labrador and the northern part of the Gulf of St Lawrence, and "Acadian" for that of the coast from Cape Breton to Cape Cod, he shows the Post-pliocene fauna of Maine and New Brunswick to be Syrtensian, and not, as at present, Acadian. He adds to the list of New Brunswick Post-pliocene fossils,—*Cardium pinnulatum*, *Astarte Banksii*, *Lepralia hyalina*, *Membranipora pilosa*, and *Cellepora pumicosa*.

CHAPTER VI.

THE TRIAS OR NEW RED SANDSTONE.

GENERAL DISTRIBUTION—RED SANDSTONES—VARIETIES OF TRAP—NEW RED FROM TRURO TO AVON ESTUARY—BLOMIDON TO BRIAR ISLAND.

BETWEEN the Drift and the New Red Sandstone, a deposit probably of the same age with the Triassic System of geologists, there is a great hiatus in the geology of Nova Scotia. During all those periods in which the middle and older Tertiaries, the Cretaceous and the Oolitic systems were produced, no rocks appear to have been formed within its area, or if they were formed they have been swept away. This remark applies not only to Nova Scotia, but to an immense region extending through New Brunswick, Canada, and the Northern United States; and, in some directions, far beyond the limits of those countries. During those long periods, these regions, thus destitute of the newer Secondary and Tertiary rocks, may have been in the interior of a great continent, or in the fathomless depths of an ocean where no sediment was being deposited; but whatever their condition, they retain no geological monuments of the lapse of time. In passing, then, from the Boulder formation to that which for convenience we may call the *New* Red Sandstone, to distinguish it from rocks of similar character but greater age, the reader may be reminded by a glance at the Table in Chapter II., that we are passing at one leap over a great part of the earth's geological history.

The distribution of the New Red Sandstone, as shown on the map, indicates that, when it was deposited, the form and contour of the country already made some approach to those which it still retains. Just as the marsh mud lines the coasts of the Bay of Fundy, so do we find the New Red occupying an inner zone, and appearing to have been deposited in a bay a little wider and longer than the present one. It is indeed to this bay district that, in Nova Scotia and New Brunswick, the New Red has been chiefly confined, and it may have been deposited in circumstances not very dissimilar from those of the present marshes, except that the older deposit is accompanied by evidence that

active volcanoes poured out their lavas on the grandest scale in the waters and on the shores of the bay while its sandstones were being formed. While the New Red Sandstone of Nova Scotia is limited to the Bay of Fundy, we have evidence in the wide extent of the same formation in Prince Edward Island, that a similar deposit was in progress in the Gulf of St Lawrence. In the gulf, however, unlike the bay, we do not find the New Red along the coasts, but in an isolated patch separated on all sides from the continent. I may remark here, that the New Red Sandstone, though patches of it are scattered over several parts of North America, is nowhere very extensive. To the southward of Nova Scotia it re-appears in Connecticut, where it extends over a considerable area in the valley of the river; and in New Jersey, where another band commences that extends a great distance to the south-east, some isolated patches occurring as far south as North Carolina.

The aqueous rocks of the New Red Sandstone period in Nova Scotia and Prince Edward Island are principally coarse and soft red sandstones with a calcareous cement, which causes them to effervesce with acids, and contributes to the fertility of the soils formed from them. In the lower part of the formation, there are conglomerates made up of well-worn pebbles of the harder and older rocks.

The volcanic rocks of this period are of that character known to geologists as *Trap*, and are quite analogous to the products of modern volcanoes; and, like them, consist principally of *Augite*, a dark green or blackish mineral, composed of silica, lime, and magnesia, with iron as a colouring material. Various kinds of trap are distinguished, corresponding to the varieties of modern lavas. Crystalline or basaltic trap is a black or dark green rock, of a fine crystalline texture, and having on the large scale a strong tendency to assume a rude columnar or basaltic structure. Amygdaloid or almond-cake trap is full of round or oval cavities or air bubbles, filled with light coloured minerals introduced by water after the formation of the rock. This represents the vesicular or porous lava which forms the upper surface of lava currents, just as the basaltic trap represents the basaltiform lava which appears in their lower and more central parts. The only difference is, that in the amygdaloid the cavities are filled up, while in the modern lavas they are empty. In some old lavas, however, the cavities are already wholly or partially filled. A third kind of trap, very abundant in Nova Scotia, is Tufa or Tuff, or volcanic sandstone, a rock of earthy or sandy appearance, and of gray, greenish, or brown colour. It consists of fine volcanic dust and scoriæ, popularly known as the ashes and cinders of volcanoes, cemented together into

a somewhat tough rock. Modern tufa, quite analogous to that of the trap, is very abundant in volcanic countries, and sometimes sufficiently hard to be quarried as a stone.

As the new red sandstone and trap are formations of one period, and differ only in origin, it will be convenient to consider them together. I shall therefore proceed to describe these two rocks as they appear in connexion in different parts of Nova Scotia, New Brunswick, and Prince Edward Island, and then notice their fossil remains and useful or interesting minerals.

1. *Truro and South Side of Cobequid Bay.*

In the valley of the Salmon River, four and a half miles eastward of the village of Truro, the eastern extremity of the New Red Sandstone is seen to rest unconformably on hard reddish brown sandstones and shales, belonging to the lower part of the Carboniferous system, and dipping N. 80° E. at an angle of 40°. At this place the overlying formation is nearly horizontal, and consists of soft and rather coarse bright red silicious sandstones. Southward of Truro, at the distance of less than a mile, the horizontal soft red sandstone is seen, in the banks of a brook, to run against hard brownish grits and shales, dipping to the eastward at angles varying from 45° to 50°. Westward of this place, the red sandstones extend in a narrow band, about a mile in width, to the mouth of the Shubenacadie, ten miles distant. This band is bounded on the north by Cobequid Bay, and on the south by highly inclined sandstone, shale, and limestone of the Lower Carboniferous series. In the coast-section, between Truro and the Shubenacadie, the red sandstone presents the same characters as at the former place, except that, near the Shubenacadie, some of the beds, which, like most of the red sandstones of Truro, have a calcareous cement, show a tendency to arrangement in large concretionary balls.

West of the mouth of the Shubenacadie, the red sandstone ceases to form a continuous belt, but occurs in several patches, especially at Salter's Head, Barncote, and Walton. At the latter place, it is seen to rest on the edges of sandstones and other rocks of the Lower Carboniferous system, affording a very fine example of that *unconformable* superposition which in geology proves the underlying formation to have been elevated and disturbed before the overlying beds were deposited upon it. This appearance is represented in Fig. 25, and was thus described by the writer in a note supplementary to his paper on the New Red Sandstone of Nova Scotia, and communicated to the Geological Society in 1852:—

Fig 25.—*Section on the West Side of the Mouth of Petite River.*

S. N.

(*a*) Carboniferous Strata, highly inclined. (*b*) Triassic Red Sandstone.

"I had in the past summer an opportunity of examining these beds at Walton (Petite) and other places, and was much gratified by finding that the New Red might be traced, as a narrow and occasionally interrupted band, from the mouth of the Shubenacadie nearly to the mouth of the Avon; thus connecting as far as possible the distinct patches of New Red described in my former paper. At some points also I found very distinct coast-sections, showing the unconformable superposition of the New Red on the Lower Carboniferous beds. A good instance of this occurs at Petite River.

"Near the mouth of the river, the Lower Carboniferous formation appears with the same characters observed at Windsor and on the Shubenacadie. It includes a large body of gypsum, extensively quarried for exportation, and a bed of limestone with veins of oxide of manganese. In the neighbourhood of these beds, the softer rocks have been denuded and do not appear. Still nearer the mouth of the river, however, there is a distinct section, showing black shales, with calcareous bands, dipping at a high angle to the south, and underlying the beds above mentioned. In a short space these beds become contorted, and then dip steeply to the north.

"Succeeding these black shales, in ascending order, the Lower Carboniferous rocks are seen in the section. These beds probably underlie the gypsum and limestone, which would recur on the north side of the anticlinal formed by the black shales if the section extended sufficiently far. Before reaching the extremity of the point on the east side of the river, however, the edges of the beds sink to the level of the sea, and the lower members of the New Red are unconformably superimposed upon them. It is a somewhat instructive fact that the beds of the underlying series are at this place both redder and softer than the overlying New Red Sandstone."

I notice this section particularly, because it gives a clear conception

of the manner in which the New Red rests on the older Carboniferous beds, wherever it is in contact with them.

2. *Blomidon to Briar Island.*

Westward of Walton, the estuary of the Avon River and Minas Basin make a very wide gap in the New Red Sandstone. On the western side of Minas Basin, however, this formation attains its greatest width and grandest proportions; and as this coast affords the finest opportunity in the province for studying all the members of the formation and their mutual relations, I shall describe it in detail with the aid of the section, Fig. 26.

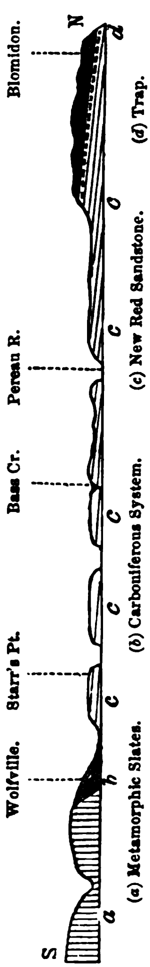


Fig. 26.—*Section from Horton to Cape Blomidon.*

Blomidon is the eastern extremity of a long band of trappean rocks, forming an elevated ridge, named in the greater part of its length the "North Mountains." This ridge is about 123 miles in length, including two insular portions at its western extremity, and does not exceed five miles in breadth, except near Cape Blomidon, where a narrow promontory, terminating in Cape Split, extends to the northward. The trap of the North Mountains presents to the Bay of Fundy a range of high cliffs, and is bounded on the inland side by soft red sandstones, which form a long valley separating the trappean rocks from another and more extensive hilly district occupied principally by metamorphic slates and granite. The trap has protected the softer sandstones from the waves and tides of the bay, and probably also from older denuding agents; and where it terminates, the shore at once recedes to the southward, forming the western side of Minas Basin, and affording a cross section of the North Mountains and the valley of Cornwallis.

At Cape Blomidon, the cliff, which in some parts is 400 feet in height, is composed of red sandstone surmounted by trap. The sandstone is soft, arranged in beds of various degrees of coarseness, and is variegated by greenish bands and blotches. It contains veins of selenite and fibrous gypsum, the latter usually parallel to the containing beds, but sometimes crossing them obliquely. I found no fossils in it; it dips to the north-west at an angle of 16°. Resting on the sandstone, and appearing to dip with it to the north-west, is a thick bed of

amygdaloidal trap, varying in colour from gray to dull red, but in general of grayish tints. It is full of cavities and fissures; and these, as well as its vesicles, are filled or coated with quartz, in different states, and with various zeolites, to be noticed hereafter, especially heulandite, analcime, natrolite, stilbite, and apophylite, often in large and beautiful masses of crystals. In its lower part there are some portions which are scarcely vesicular, and often appear to contain quartz sand like that of the subjacent sandstone. Above the bed of amygdaloid is a still thicker stratum of crystalline basaltic trap, having a rude columnar structure.

The columnar trap of Blomidon, in consequence of its hardness and vertical joints, presents a perpendicular wall extending along the top of the precipice. The amygdaloid beneath, being friable and much fissured, falls away in a slope from the base of this wall, and the sandstone in some places forms a continuation of the slope, or is altogether concealed by the fallen fragments of trap. In other places the sandstone has been cut into a nearly vertical cliff, above which is a terrace of fragments of amygdaloid.

Northward of Cape Blomidon, the north-westerly dips of the sandstone and trap cause the base of the former to descend to the sea-level, the columnar trap, which here appears to be of increased thickness, still presenting a lofty cliff. Southward of the cape, on the other hand, the amygdaloid and basalt thin out, until the red sandstones occupy the whole of the cliff. It thus appears that the trap at Blomidon is a conformable bed, resting on the sandstone, exactly as in some places on the opposite shore, to be described hereafter.

The coast section between Blomidon and Horton, as seen near Pereau River and Bass Creek, and at Starr's Point, Long Island, and Bout Island, exhibits red sandstones, with north-west dips at angles of about 15°, and precisely similar in mineral character to those of Blomidon, except that near Bass Creek some of them contain layers of small pebbles of quartz, slate, granite, and trap. The whole of these sandstones underlie those of Blomidon, and resemble those which occupy the long valley of Cornwallis and the Annapolis River, westward of this section. In this valley, the red sandstone, in consequence of its soft and friable nature, is rarely well exposed; but in a few places in Cornwallis, where I observed it, it has the same dip as on the coast. The comparatively high level of the sandstone, where it underlies the trap, shows that the present form of this valley is in great part due to denudation; and the trap itself must have suffered from this cause, since fragments of it and of the quartzose minerals which it contains, are frequent in the valley of Cornwallis, and along the base of the slate hills to the southward.

We may now consider the relations of the red sandstone of Cornwallis to the other formations bounding it on the south. Near Kentville, seven miles westward of the direct line of section from Blomidon to Horton, the red sandstone, with its usual north-west dip, rests against clay-slate having a high dip to the N.N.E., and belonging to a series of similar rocks apparently equivalents of the Silurian system. In tracing the boundary of the slate eastward of this place, along the south side of Cornwallis River, its junction with the red sandstone is not again observed; and at Wolfville the slates support hard gray sandstones, composed of the materials of granite, with some beds of brownish sandstone. These rocks were observed in one place to dip to the N.E., and in another to the N.N.W. They are separated from the red sandstones of Bout and Long Island, and Starr's Point, by a wide expanse of marsh, and by the estuary of the Cornwallis River. In Lower Horton, and between that place and Halfway River, gray sandstones, similar to those of Wolfville, are seen to support black shales and dark sandstones, with *Lepidodendra* and other fossil plants of carboniferous forms, and dipping to the N.E., N., and N.W. These beds continue to the mouth of the Avon estuary, where they form the cliffs of Horton Bluff, at the northern end of which they are seen dipping to the south. They are then concealed by boulder clay, which with marsh forms the shore for nearly a mile. Beyond this, in a small point called Oak Island, are seen a few beds of coarse red sandstone with some finer red beds and grayish bands. These rocks dip to the N.N.W., and form a continuation, and the eastern extremity, of the New Red Sandstone of the Horton Islands and Cornwallis.

In describing this section, I have merely copied my notes upon it, and have purposely refrained from drawing any inferences or giving any explanations. To begin with Blomidon—the crystalline trap at its summit, which rises abruptly in huge irregular columns, is an ancient current of molten rock or lava, which has flowed over and cooled upon the surface on which it now rests. It slopes gently toward the north-west, as if it had flowed toward the bay, but there is no volcanic dike or other evidence of the ejection of lava from beneath on that side, and it is more than probable that the orifice from which it was poured forth was to the westward along the range of which Blomidon is the eastern extremity, or northward toward Cape Split. From the appearance of the mountain-top that rises above the vertical cliff, there may have been more than one overflow of the volcanic matter. Before this great bed of basaltic trap flowed forth, the surface on which it rests had been thickly covered with volcanic ashes and scoriæ, which, consolidated by pressure and by infiltration of mineral

matters, now form the thick bed of amygdaloid and tufa intervening between the columnar trap and the red sandstone. This is precisely what we find to be the case in modern volcanic eruptions. The first violent explosions in such cases usually eject immense quantities of dust and fragments of old lavas, which are blown or ejected to great distances, or if they fall into the sea, as was most probably the case at Blomidon, are scattered in layers over its bottom. Over these ejected scoriæ and ashes the lava currents which issue subsequently are poured. We need not be surprised that we do not now perceive any regular volcanic mountain or vent at Blomidon, for independently of the action the waters may have exerted on it when being formed, we know that great denudation has taken place in the Drift period, and under the wasting action of the present frosts and tides. The minerals mentioned as occurring in the trap are all either silica or silicates,—that is, compounds of silica with the alkalies potash and soda, or the earths, as alumina, lime, etc. They are produced by the solvent action of water, which, percolating through the trap, dissolves these materials, and redeposits them in fissures and cavities. Below the amygdaloid, we have a thick series of beds of red sandstone—mechanical detritus deposited by water, and probably in great part derived from the waste of the sandstones of the Carboniferous system. The gypsum veins which traverse it were probably deposited by waters which had dissolved that mineral, in passing through the great gypsum-beds which occur in the older system last mentioned.

The history of this fine precipice is then shortly as follows. In the Triassic era, thick beds of sandstone were deposited off the coasts of Horton, just as the red mud and sand of the flats are now deposited. Volcanic phenomena on a great scale, however, broke forth from beneath the waters, scoriæ and dust were thrown out, and spread around in thick beds, and currents of lava were poured forth. Subsequently the whole mass was elevated, to be again submerged under the boulder-bearing sea, by which, and the present atmospheric and aqueous agencies, it was worn and wasted into its present form. Still the work of decay goes on; for yearly the frosts loosen immense masses from its brow, and dash them to the beach, to be removed by the ice and the tides, and scattered over the bottom of the bay. The rains and melting snows also cut huge furrows down its front. These agencies of destruction as yet, however, only add to the magnificence of this noblest of all our sea-cliffs. The dark basaltic wall crowned with thick woods, the terrace of amygdaloid, with a luxuriant growth of light green shrubs and young trees that rapidly spring up on its rich and moist surface, the precipice of bright red sandstone, always clean

and fresh, and contrasting strongly with the trap above and with the trees and bushes that straggle down its sides, and nod over its deep ravines,—constitute a combination of forms and colours equally striking if seen in the distance from the hills of Horton or the shore of Parrsboro', or more nearly from the sea or the stony beach at its base. Blomidon is a scene never to be forgotten by a traveller who has wandered around its shores or clambered on its giddy precipices.

From the shore of Blomidon, we may follow the trap formation in a continuous ridge without a break to Annapolis Gut. On the south side, the trap slopes down in rounded and abrupt eminences into the red sandstone valley. On its summit it is somewhat level, though divided into a number of long rolling ridges, probably the effect of denuding agents on the edges of beds of trap of unequal hardness. The bay shore presents to the sea a range of cliffs and precipices often overhanging or vertical, or rolled down into shapeless heaps of rubbish by the frost and the undermining action of the waves. Huge landslips occur every spring from these causes, covering acres of the shore with their ruins, and affording a rich harvest for the mineralogist who may visit the shore after one of these falls. The amount of debris annually thrown down and removed in this way is enormous. The cliffs are usually composed of alternate layers of soft and hard trap and tufa, they are traversed by innumerable fissures, and the general dip is seaward. In addition to these circumstances, the ice annually removes large quantities of fragments from the shore, so that a cliff does not long continue to be protected by the masses that have fallen from it. Hence the whole shore wastes rapidly, with the exception of those places where beds of hard basaltic trap run down to the sea level, and form inclined planes against which the sea rages in vain.

A very remarkable deviation from the ordinary regularity of the coast line of the trap occurs at Cape Split, which forms a prolongation of the Blomidon shore to the north-westward. The dip of the Blomidon basalt gradually brings it down to the sea-level, and toward Cape Split it either thickens, or portions which have retired from the cliff at Blomidon come forward into the shore precipices; for toward the cape a cliff more than 300 feet in height seems to be composed of compact and columnar trap, which extends in a promontory and series of islands and reefs far out into the bay. The appearances at this place render it possible that a trappean dike or dikes, indicating the point or line of ejection of the great basaltic bed of Blomidon, may appear in these cliffs toward Cape Split. I have not, however, been able to study them so closely as to ascertain decisively whether this is the case. There seems no reason to doubt, at least, that the

line from the summit of Blomidon to Cape Split marks the direction of one of the greatest lava streams of the region.

At the extremity of the long continuous range extending westward from Blomidon, in the cliff forming the east side of Annapolis Gut, we find the trap, as at the former place, forming a thick bed resting on the red sandstone, and dipping to the northward; and there can be no doubt, from the appearances observed at several places along the coast, that the same arrangement prevails throughout the entire ridge.

Annapolis Gut is a deep channel separating the trap of the promontory of Granville from the western prolongation of the formation. This channel forms the only outlet of Annapolis Basin and the rivers emptying into it. It is of great depth, and the tides rush through it with terrible rapidity. The trap on its west side is more largely developed than on the Granville side. It attains a greater width and height, and contains a larger mass of compact and basaltic trap. This circumstance, in connexion with the narrowing of the valley by a spur of metamorphic rocks on the south, has probably caused the currents of the Drift period to excavate the present outlet. Had it not been for these circumstances, the waters of the Annapolis River would probably have flowed into St Mary's Bay; and the Annapolis Basin, probably the finest sheet of salt water in the province, and its remarkable and picturesque outlet, would not have existed. The sandstone near the town of Digby is somewhat hard, and contains concretions of transparent calc spar. It passes under the southern edge of the trap, but cannot be seen toward the centre of the ridge, where the precipitous side of the "Gut" consists of compact and basaltic trap extending downward to the water-level. In one place, I observed basalt with its pillars nearly horizontal,—an evidence that here a dike of molten rock had been ejected from beneath. Toward the entrance of the gut on the Digby side, the coast becomes low, and amygdaloid is seen in low cliffs and on the slopes of the hills, while sheets of compact trap run downward into the sea with scarcely any abrupt cliff or bank.

In Digby Neck, the sandstone is well exposed on the side fronting St Mary's Bay, and compact and amygdaloidal trap rest upon it, and dip northward toward the Bay of Fundy. This long promontory, though only from two to three miles in width, consists of two ridges, one forming the cliffs that front St Mary's Bay, the other sloping toward the Bay of Fundy; while between them is a narrow and almost level valley, with several little lakes and ponds arranged in a line along its bottom. The rock in this valley appears to be amyg-

daloid, and it is probably owing to this circumstance that the valley has been scooped out, while the edges of the beds of more compact trap remain as ridges. This at least is the explanation which appears most probable from the structure of all parts of the ridge that I have visited, except the very singular and romantic spot named Sandy Cove. At this place a deep cove penetrates about one-fourth across the ridge from the south, between precipitous cliffs of trap resting on amygdaloid, and apparently with a southerly dip; or, at all events, without that decided dip to the north which prevails over the greater part of this trappean ridge. Opposite the southern cove, there is on the north side of the ridge a shallower cove, and between is a little lake, on either side of which rise lofty beetling cliffs of basaltic trap, which appear to be parts of a thick bed dipping to the northward. I have marked in my notes the query—Can this be a volcanic crater? and I find that the same thought has occurred to other geologists who have visited the spot. It may have been so; but it is perhaps more probable that the ridge has here been cracked across by a fissure caused by earthquake disturbances; and that the currents of the Boulder formation period have passed through and widened the chasm. Whatever the causes of its present appearance, Sandy Cove is more like something a poet or painter might dream of, than like an actual reality in our usually tame province of Nova Scotia.

Though the trap ridge is very narrow at Digby Neck, it appears that this rock occupies a considerable breadth beneath the waters of the Bay of Fundy. I have already mentioned that the "Neck" consists of two ridges, with a valley between. Now under water there are three similar ridges, the outer being nine miles distant from the shore. They are thus described by Mr Perley, in his Report on the Fisheries of New Brunswick; and his statements were corroborated by information which I obtained from gentlemen resident on this coast:—

"From Black Rock down to Briar Island, along the whole south shore, there are three fishing banks or ledges, lying parallel to the shore, outside each other; their respective distances from the coast have acquired for them the designations of the three-mile ledge—the five-mile ledge—and the nine-mile ledge. Between these ledges there are sixty fathoms of water, but on the crown of each ledge, thirty fathoms only. The three-mile ledge, and the five-mile ledge, extend quite down to Briar Island; but the nine-mile ledge can only be traced down the bay about fourteen miles below Digby Gut, abreast of Trout Cove, where it ends in deep water. Below Digby Gut, the three-mile ledge and five-mile ledge are composed of hard gravel and

red clay; above the gut, the three-mile ledge has a rough, rocky bottom, on which anchors are frequently lost. Each of these ledges is about a mile in width, the outer one something more; between them the bottom is soft mud."

The trap of Digby Neck is remarkable for the large quantity of jasper and other coloured varieties of quartz contained in it. Red jasper is especially abundant; amethyst, stilbite, and laumonite are also frequent. I have collected all these minerals near Sandy Cove, as well as micaceous specular iron ore, a mineral which I have not observed elsewhere in the trap district, though it abounds in our more ancient igneous and altered rocks, and is also a not infrequent product of modern volcanic action; the iron being apparently sublimed in a state of vapour from the intensely heated mass of molten rock beneath. This is probably its origin at Sandy Cove, where it occurs in brilliant little crystalline plates embedded in a quartzose matrix, and projecting from the sides of cavities in the fissures of the trap. Its occurrence here lends some countenance to the conjecture already stated, that a focus of igneous activity may have been in or near this place. It is not in sufficient quantity to be of importance for mining purposes.

At the extremity of Digby Neck, we find another deep transverse ravine cut through the ridge, and separating Long Island, which geologically is a perfect continuation of the Neck. The sides of this strait, which is named Petite Passage, as far as I examined them, consist principally of amygdaloid, the cavities of which have been lined with bright green chlorite before they have been filled with crystalline zeolitic matter.

The water of Petite Passage is beautifully clear, the tides rush through it with great force, and its rocky bottom is covered with sea-weeds; the finer and more beautiful varieties of which are very abundant on this outlying tract of rocky coast. It is probably the abundance of these seaweeds on the "ledges" before mentioned, that supports the marine creatures that attract to these coasts the cod, torsk, pollack, haddock, halibut, and herring that abound in summer, and furnish a comfortable subsistence to the numerous fishermen who inhabit Long Island and Briar Island. The great Albecore or King Mackarel, *Thynnus vulgaris?* the Sea Wolf, *Anarrhicas lupus;* and the Sturgeon, *Accipenser oxyrhinchus*, are also caught in these waters and in St Mary's Bay, but are not much valued by the fishermen.

On reaching the extremity of Long Island, another strait, the Grand Passage, appears. On the opposite side of this, we see the thriving village of Westport, on Briar Island, the *ultima thule* of Nova Scotia in this direction, and one of the most active and intelligent

fishing communities in the province. Briar Island is the extreme western end of the trappean ridge, which is, however, prolonged beyond the land in a submarine ledge. It consists entirely of basaltic trap, very regularly divided into columns, which may be seen both as a pavement on many parts of the beach, and in lofty precipices which rise to their greatest height on the south-west side of the island, where they form a perpendicular wall several hundred feet in height, and adorned with buttresses, outlying towers, and pinnacles, such as basaltic cliffs alone can produce in their full perfection. I was so fortunate as to be detained several days at Briar Island by a south-west gale, and had the pleasure of seeing the Atlantic swell bursting in all its grandeur on these iron-bound shores (Fig. 27).

Fig. 27.—*Basaltic Cliffs, West End of Briar Island.*

The red sandstone is seen to underlie the trap of Digby Neck for several miles below the head of St Mary's Bay, but beyond this I did not again observe it. Gesner states, however, that a small patch of it can be observed at low tide beneath the trap of Briar Island. This interesting fact I had no opportunity of verifying, owing to the stormy state of the weather during my visit.

CHAPTER VII.

THE TRIAS OR NEW RED SANDSTONE—*Continued.*

TRURO TO CAPE D'OR—GENERAL REMARKS—MINERALS OF THE NEW RED SANDSTONE AND TRAP.

3. *North Side of Cobequid Bay and Minas Basin and Channel.*

RECOMMENCING at Truro, we may now consider the stripe of New Red Sandstone, with occasional masses of trap, which extends with several interruptions as far as Cape d'Or. Northward of Truro, the red sandstone meets and overlies unconformably the Carboniferous grits, shales, limestone, and gypsum of the North River and Onslow Mountain. Its boundary in this direction is about three miles distant from the bay, and it occupies the low country; the Carboniferous rocks rising from under its edges into hills of considerable elevation. From the North River it extends in a band about three miles in width to De Bert River, where an apparently insulated patch of Lower Carboniferous rocks projects through it. These last appear at the bridge, and consist of limestone, with fossil shells characteristic of the Lower Carboniferous period, gypsum, and hard brownish sandstone. They dip at a high angle to the north-east, while the New Red Sandstone, which laps around them, dips at a small angle to the south-west. This limestone and gypsum, as well as other rocks of the same age, were long believed to belong to the Triassic period, and it was only after their true age had been ascertained by careful comparison of a number of sections, and the identification of the fossil remains with those of the Carboniferous period in other countries, that their true geological position was appreciated. This very locality at the De Bert River, owing to the similarity of the Lower Carboniferous sandstones to those of the New Red, and to the circumstance that the former have been ground down and their debris mixed up with the latter, is at first sight one of the most deceptive in the province, and might readily lead a geologist unacquainted with other more distinct sections into an error on this subject.

As the section at this place is remarkably obscure, I copy from my

notes the following memoranda of the appearances. On the south side of the river, near the bridge, there are gray and brown shales, red sandstone, red grit, and conglomerate, with high dips and disturbed. These are evidently Lower Carboniferous, and quite different from the horizontal soft red sandstones which appear lower down on the same bank. On the north side, at the end of the bridge, are dark red grit and conglomerate, grayish conglomerate, marly and shaly beds with gray calcareous concretions, and a vein of calcareous spar. They dip N.E. and N.N.E. 38°. The limestone and gypsum seen a little below the bridge are associated with these beds, the whole being Lower Carboniferous, as indicated by the fossils of the limestone. In the road-cutting, soft red sandstone and conglomerate overlie these beds, and though they have a steep false bedding, I believe they are New Red and unconformable. In the same road-cuttings, these upper beds are seen to be made up of the debris of the lower, with which they are confusedly intermixed at their confines, the underlying marls in some places rising like veins into the sandstone above. At Folly River the New Red is soft and fine grained, with greenish stains and layers, and has a very slight northerly dip. In the point opposite the village, sandstones, apparently the continuation of the older formation seen at the bridge, dip to the N.E. at a very high angle.

Within this islet of Lower Carboniferous rock, the New Red Sandstone extends up the Folly River, which runs into the same estuary with the De Bert, for about five miles. Its dip increases until it amounts to 50°, and the lowest beds rest against the disturbed Carboniferous rocks which occupy the bed of the river between this place and the base of the Cobequid Mountains. Near their junction with the older rocks, the red sandstones become coarse and pebbly.

Westward of Folly River, the belt of red sandstone gradually decreases in width, and begins to contain in its lower part thick beds of conglomerate, made up of pebbles derived from the older rocks to the northward. Near Portapique River, and somewhat removed from the coast, there is an eminence that I have not visited, but I was informed by a gentleman, very familiar with this part of the country, that it consists of trap. If so, this is the first appearance of that rock in this direction.

The new road along the bank of Great Village River, between that village and the Acadian iron mine, exhibits an interesting section of this formation, consisting of red sandstones and red conglomerates with imperfectly rounded pebbles, and often with oblique or false bedding. They often rise into cliffs of considerable height, and have

a moderate dip to the southward. About three miles from the Great Village they terminate, resting unconformably on the edges of Carboniferous rocks dipping at high angles to the north.

Economy Point, as well as a detached reef named the Brick Kilns lying off the point, consists of New Red Sandstone, which here has in consequence a considerable breadth. It has a slight dip to the south. In the banks of Economy River, the red sandstone and conglomerate which, near the coast, dip to the southward at a low angle, undulate as they approach a hill of hard Lower Carboniferous rocks at no great distance from the shore. Behind these they again appear with a south-west dip, and are again succeeded by Lower Carboniferous rocks which continue to the base of the hills. The ridge of older rock which here divides the red sandstone, is probably a point or promontory connected with the mass of the Carboniferous rocks to the westward.

In Gerrish's Mountain, six miles west of Economy River, the red sandstone and conglomerate are overlaid by amygdaloidal trap, and having been protected by it from denudation, rise into an eminence nearly 400 feet high. At Indian Point, the southern extremity of Gerrish's Mountain, the trap and red sandstone form a bold precipitous cliff, and are continued along the picturesque rocky chain of the Five Islands, in two of which the red sandstone is seen to underlie the trap.

The isolated trap eminences at this place are probably the remains of a continuous lava current, and it is interesting that the direction of the chain of islets corresponds with that of the great trap ridge on the opposite side of the bay. To a traveller who has passed along the level shores of Londonderry and Onslow, and toward the close of day ascends the steep side of Gerrish's Mountain, the view which greets him at the summit is of the most grand and striking character. The rocky chain of the Five Islands, and the pretty inlet and settlement on the shore within them, lie at his feet. In front are the waters of Minas Basin stretching far to the westward. On the one hand is the rugged and picturesque trappean shore extending toward Parrsboro', with the Cobequid Mountains ranged behind it. On the other, Blomidon and Cape Split tower in the distance. I may remark here, that for grandeur and beauty of coast scenery, this part of Minas Basin and the Minas Channel are not surpassed by any part of the eastern coast of North America.

It will be seen, on consulting the map, that at the Five Islands three great geological formations approach each other, so that within a very limited space the Trap, the New Red, the Carboniferous system,

and the older metamorphic rocks may be studied, and specimens of their characteristic minerals obtained. Hence, at various times, this locality has had the reputation of producing useful minerals of different descriptions. The latest instance of this led to the formation of a copper mining company in London, which, after a very fair promise of success, was broken up, owing to a deficiency of the ore, which on trial was found by no means to warrant the reports that had been published respecting it. The trap which forms the summit of Gerrish's Mountain is a huge bed resting on red sandstone, on which at the high cliff of Indian Point it is seen to rest. The trap at this place is traversed by a number of narrow and irregular veins of magnetic iron ore, mixed with the gray sulphuret and oxide of copper. Specimens of this substance were sent to me, many years since, by the late George Duncan, Esq. of Truro, and I was somewhat struck by the singular appearance and composition of the mineral, which was stated to be found in great quantity. From my knowledge of the superficial character of the trap, and the smallness and irregularity of the metallic veins found in it, I rather discouraged Mr Duncan from speculating on it, though some specimens seemed sufficiently rich to be useful as copper ores. It appears, however, that a very favourable report was given by an English mining engineer, and operations were commenced in consequence, but were soon abandoned.

Between Five Islands and Swan Creek, ten miles distant, an excellent coast section, rising in many places into lofty cliffs, shows the New Red Sandstone and Trap, as well as the underlying Carboniferous strata. As this section is an interesting specimen of the complicated appearances that may result from the eruption of volcanic rocks through stratified deposits, I shall give a detailed description of the arrangements observed.

At the mouth of Harrington River, opposite the Five Islands, the Carboniferous rocks approach the shore very closely; and as seen in the west side of the river, consist of black shales and dark-coloured sandstones with *Cordaites* and other fossil plants. They dip at high angles to the south, and are met by the New Red Sandstone dipping gently to the southward. The sandstones of the newer formation here contain little conglomerate, and are variegated by numerous greenish bands and blotches. They occupy the shore for some distance, and then contain a thick bed of trap conglomerate, consisting of large partially rounded fragments of amygdaloidal and compact trap, united by a hard brownish argillaceous cement. At a short distance westward, another bed of trap conglomerate of the same kind appears in the cliff. It is overlaid by a bed of dark clay, filled with angular

fragments of black shale constituting a kind of breccia. The sandstone underlying this bed of trap contains small nodules of selenite and narrow veins of reddish fibrous gypsum. No other volcanic rocks occur in the coast section near these trap conglomerates. Westward of this place, the section is occupied for about three miles by soft red sandstones with greenish bands, dipping generally to the south-west: some of them are divisible into very thin layers, whilst others are compact and form beds several feet in thickness.

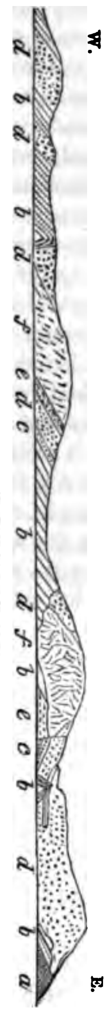


Fig. 28.—*Coast Section East of Swan Creek.*

(*a*) Shales and Sandstone of Carboniferous System, dip. E.N.E.
(*b*) New Red Sandstone, dips to S.W. (*c*) New Red Sandstone with fragments of Trap.
(*d*) Trap Conglomerate and Breccia. (*e*) Amygdaloidal Trap. (*f*) Crystalline Trap.

Near Moose River, the red sandstones meet black shales and hard gray sandstones of the Carboniferous system, containing *Cordaites*, *Ferns*, and *Lepidodendra*.*

At this place the junction of the two groups of rocks was not, at the time of my visit, well exposed in the cliff, and had the appearance of a fault; but as seen in the horizontal section on the beach, the red sandstone with a south-west dip seems to overlie unconformably the carboniferous strata, dipping at a high angle to the E.N.E. On the west side of Moose River the Carboniferous strata include three large masses of trap which have altered the grits and shales in contact with them, causing them to assume reddish colours. Beyond the last of these masses of trap, the shales and grits, there dipping to the north and north-east, have some red sandstone resting on their edges, and are succeeded by another great mass of trap, forming a lofty cliff, and in part at least resting on soft red sandstone which it must have overflowed when in a fluid state. At the western side of this mass, or rather bed of trap, its upper surface is seen to dip to the W.S.W., and is conformably overlaid by red sandstones similar to those already described. These continue with various dips to a cove where there is a break in the section, westward of which the coast exhibits the interesting and complicated appearances which I have endeavoured to represent in Fig. 28.

* These fossil plants will be described in treating of the Coal Measures.

The lower part of the cliff, on the western side of the cove above mentioned, consists of hard, black, and reddish shales and grits, like some of those seen near Moose River, with a steep dip to the E.N.E. Resting on the edges of these are a few beds of red conglomerate and sandstone with greenish bands, dipping to the south-west, and apparently a remnant of more extensive beds. An enormous mass of trap conglomerate forms a high cliff towering above this little patch of sandstone, and is seen a little farther on to contain a wedge-shaped bed of red sandstone, and at its western extremity rests on red sandstone mixed with fragments of trap.* Here the trap conglomerate seems to be cut off by a fault, and abuts against a great trappean mass, composed, in ascending order, of amygdaloidal trap, a wedge of red sandstone extending over part of the surface of the amygdaloid, a great bed of crystalline trap, and a bed of trap conglomerate. The western side of this mass rests on an apparently denuded surface of soft red sandstones, with S. S.W. dip. These are overlaid by another trappean mass, consisting of beds which appear to dip conformably with the underlying sandstones. At its western side it abuts against greatly disturbed red sandstones succeeded by other red sandstones dipping to the southward, and extending as far as Swan Creek.

On the west side of Swan Creek, the soft red and variegated sandstones are seen to dip to the north at an angle of 30°, and are underlaid by a bed of trap conglomerate, which rests against disturbed strata of a composition different from any previously occurring in this section. They consist of laminated, compact, and brecciated gray limestone, a bed of white gypsum, hard reddish purple and gray marls and sandstones, some of them with disseminated crystals of specular iron ore. I saw no fossils in these beds, but as they are identical in mineral character with some parts of the gypsiferous member of the Carboniferous group, and have evidently been disturbed and altered before the deposition of the overlying trap conglomerate and red sandstone, I have no doubt that they belong to the Carboniferous system, the sandstones and shales of which, with some trappean rocks, occupy the cliff between this place and Partridge Island, five and a half miles distant. The New Red Sandstone in the vicinity of Swan Creek appears to form a small synclinal trough, occupying an indentation in the Carboniferous rocks, and probably extending only a short distance westward of the mouth of the creek. The two islands near

* This section was examined in 1846. When I revisited the place in 1850, the front of this mass of trap conglomerate had fallen, and formed a huge slope of fragments.

Swan Creek are detached masses of trap, resting on or rising through red sandstones, which at low tide are seen to extend between them and the shore. The red sandstone and trap, occurring in the section between Five Islands and Swan Creek, appears to be a very narrow band, extending parallel to the coast; and as the section is nearly in the general direction of the strike of the formation, it is probable that some of the trappean masses above described are portions of beds disconnected by faults and denudation.

Many beautiful crystallized minerals occur in the trap rocks of the sections described. The masses near Moose River contain cavities coated with opaque white varieties of quartz, in stalactitic and other imperfectly crystalline forms. Opposite the Two Islands, the fissures of the trap are lined with fine crystals of analcime and natrolite; and the fissures and vacant spaces of the trap conglomerate in the same neighbourhood contain a reddish variety of chabasite (Acadiolite) in rhombohedrons, often of large size.

At Clarke's Head, immediately west of Swan Creek, the Lower Carboniferous rocks are well exposed, including beds of limestone and gypsum, with some igneous rocks of porphyritic character, and probably much older than the Triassic period. On the top of the cliff, a bed of compact trap is seen to rest on the edges of the disturbed lower Carboniferous rocks, over which it has flowed as a lava stream.

The trap conglomerate or breccia, noticed in describing the above section, is a rock of very singular character. It consists of large fragments, often more than a foot in diameter, of amygdaloid, cemented together by a hard brownish substance. The boulder-like fragments of trap which make up this rock have probably been blown out of a volcanic orifice, and then rolled into beds by the sea, and finally cemented by a paste made up of fine volcanic mud or ashes.

Beyond Clarke's Head, the coast extending toward Cape Chiegnecto is occupied by Carboniferous rocks, for the most part in a very much disturbed condition, and it is only here and there that we meet with a small patch of New Red, and its overlying trap, the remnants of a formation once continuous throughout the whole distance.

The first of these isolated patches is Partridge Island, a high rock of trap resting at its west side on red sandstone. Though called an island, it is connected with the shore, which consists of Lower Carboniferous sandstones and shales in a vertical and contorted condition, by a shingle beach. The island itself presents a high cliff to the bay, and slopes downward on the land side. In approaching it from the east, we see a cliff of columnar trap extending from the shore to the

summit of the rock. By scrambling at low tide around the south side, we find that this, like the basalt of Blomidon, is a thick irregular bed, and that amygdaloid and tufa succeed it in descending order. On the western side these last rocks occupy nearly the whole of the cliff, and may, when examined from a distance, be seen to consist of several beds distinguishable by different shades of colour. In some lights this difference is very perceptible. On this side the basaltic trap still appears, but it forms only a thin bed, capping the amygdaloid and tufa. Under all these beds, and in the north-west corner of the island, the sandstone peeps forth, dipping to the south-east.

The trap of Partridge Island contains a variety of interesting crystallized minerals. A honey-yellow variety of stilbite, crystallized in fine sheaf-like aggregations of crystals, is especially abundant, forming veins running up the face of the cliff. Being one of the most accessible and easily explored portions of the formation, this place has been much ransacked by mineralogists and amateurs; still large quantities of fine specimens may generally be seen going to waste on its beach. Amethyst, agate, chabazite, heulandite, apophyllite, and calc spar, may also be studied in some of their most beautiful forms at Partridge Island. The whole of these minerals have been introduced by the action of water, trickling through the numerous fissures of the porous amygdaloid and tufa, rocks which perhaps, more than any others, are fitted to yield to water thus permeating them the materials of crystallized silicious compounds.

Westward of Partridge Island, vertical and contorted Carboniferous rocks occupy the shore as far as Cape Sharp, three miles distant. This promontory, which, like Partridge Island, presents a precipitous front to the bay, and slopes toward the land side, consists of trap resting on red sandstone. Here, however, trap conglomerate takes the place of the finer tufaceous matter seen at Partridge Island. It will be observed that though the red sandstone is not at these places seen very distinctly to rest on the Carboniferous rocks, the former underlies the trap at a gentle angle, and dips southwards, or from the latter, while these are contorted and disturbed in the most extreme manner, serving at least to confirm the evidence, noticed at other places, of the later date of the New Red. These contorted Carboniferous sandstones and shales must have formed a coast line, at the time when the red sand was washing in the sea, and the trap and scoriae being belched forth from submarine vents.

Beyond Cape Sharp, with the exception of the isolated mass of Spencer's Island, which I have not visited, we see nothing of the trap or red sandstone till we reach Cape d'Or, the last and noblest mass on

this coast. At Cape d'Or, as at the Five Islands, a great mass of trap rests on slightly inclined red sandstone, and this again on disturbed Carboniferous rocks, while, behind and from beneath these last, still older slates rise into mountain ridges. Cape d'Or thus forms a great salient mass standing out into the bay, and separated from the old slate hills behind by a valley occupied by the red sandstone and Carboniferous shales. Cape d'Or differs from most of the trappean masses which have been described in the arrangement of its component parts. The upper part of the cliff consists of amygdaloid and tufa, often of a brownish colour, while beneath is a more compact trap, showing a tendency to a columnar structure. The whole forms a toppling cliff, more shattered and unstable in its aspect than usual.

Cape d'Or derives its name from the native copper which is found in masses, varying from several pounds in weight down to the most minute grains, in the veins and fissures which traverse the trap. It is sometimes wedged into these fissures, along with a hard brown jasper, or occupies the centre of narrow veins of quartz and calc spar. At first sight, these masses and grains of pure copper appear to have been molten into the fissures in which we find them. On more careful consideration of all the circumstances, and those of the associated minerals, it seems more probable that the metal has been deposited from an aqueous solution of some salt of copper, in a manner similar to that of the electrotype process. Why this should have occurred in trap rocks more especially does not appear very obvious; and, indeed, when we take a piece of native copper from Lake Superior or Cape d'Or, with the various calcareous and silicious minerals which accompany it, nothing can be more difficult than to account on chemical principles for these assemblages of substances, either by aqueous or igneous causes. Nature's chemistry is often thus inscrutable in its details, for the behaviour of substances, when brought into contact with each other in the bowels of the earth, is often very different from that which they display in the laboratory; and, besides, nature's processes are not limited by time, and long continued chemical actions often produce effects which would hardly be inferred from experiments which are limited for their performance to hours or days. I have, in a paper on the cupriferous trap rocks of Maimanse in Lake Superior,* shown that the native copper of that locality must also be accounted for by aqueous causes.

The copper of Cape d'Or is not likely to become of mining importance, as it does not appear in large quantity in any one portion of the mass, and this latter is itself not of very great extent. The

* Canadian Naturalist, vol. ii.

valuable discoveries, however, which have been made on the shores of Lake Superior have in late years caused increased importance to be attached to the appearance of copper in trap rocks, and perhaps this and other cupriferous localities in the trap of Nova Scotia may deserve a more careful examination than they have yet received.*

The only remaining portion of the New Red Sandstone and Trap formation is the little insulated spot of Isle Haut, lying off Cape Chiegnecto. I have not landed on this island; but, viewed from the sea, it appears to present nearly on all sides lofty cliffs of trap.

4. *South Coast of New Brunswick.*

The following notices of the detached patches of Trias which occur on the south coast of New Brunswick, are taken from a contribution of Mr Matthew to Professor Bailey's Report on Southern New Brunswick.

Formerly, large areas of the Lower Carboniferous red sandstones of New Brunswick were regarded as Triassic, but on more careful examination it appears that this formation is limited to three small patches on the coast of the Bay of Fundy. It is probable, however, that these are but remnants of a more extensive area removed by denudation, or still beneath the waters of the bay, and perhaps continuous with the red sandstone district of the counties of King's and Annapolis in Nova Scotia.

The most important of these Triassic patches is that near Quaco Head, where the beds consist of soft red sandstones with layers of quartzose pebbles, and an overlying coarse conglomerate of a gray colour. They rest unconformably on limestone and conglomerate of Lower Carboniferous age. A few fragments of fossil wood were found in them by Mr Matthew, and, though not well preserved, their structure is evidently that of coniferous or pine trees, and the cell walls show but one row of discs,—a character which belongs to the pines of the genera *Peuce* and *Pinites*, found in Mesozoic rocks, and not to the older pine trees of the Coal formation. This fossil wood I regard as a valuable confirmation of the opinion that these red sandstones are really Triassic, as such wood is not found in any older formation. At Quaco the beds dip N.N.E., at angles varying from 25° to 45°, and their thickness is estimated by Mr Matthew at 800 feet. They show much oblique lamination, and are probably not far from the original margin of the New Red Sandstone area in this direction. The oxide of manganese

* Since the first edition of this work was published, explorations have been undertaken at Cape d'Or, and also on the opposite side of the bay, but as yet without profitable results.

occurs in irregular beds and pockets in the conglomerate at Quaco, and has probably been derived from veins of the mineral which occur in the Lower Carboniferous rocks.

Westward of Quaco the Trias occurs near Gardener's Creek, in a patch about one mile and a half long and half a mile wide. The character of the deposit is similar to that at Quaco, but the upper or conglomerate member is wanting.

Eastward of Quaco, but more than thirty miles distant, another small area of Triassic sandstone has been recognised at Salisbury Cove. The beds dip E.N.E., at an angle of 10°, and are of a paler red than at Quaco.

These remnants of New Red Sandstone on the New Brunswick side of the Bay of Fundy concur, with the similar deposits in Nova Scotia, in showing that the depression occupied by that bay had already assumed nearly its present form; and this, together with the fact that the Carboniferous rocks had been disturbed and hardened before the deposition of these later beds, affords, as Mr Matthew has well remarked, strong evidence that the New Red Sandstones of the Bay of Fundy are Triassic rather than Permian.

5. *General Remarks on the Trias of Nova Scotia and New Brunswick.*

It will be observed that, in the notes referring to the coast sections of the New Red Sandstone, I have given especial attention to its relations to the older rocks, especially those of the Carboniferous system. I have done so, because much doubt formerly existed as to the precise limits of this formation. The earlier writers on the geology of Nova Scotia and New Brunswick associated it with the red sandstones and gypsums of the Carboniferous period, and described the whole as "New Red;" and it was not until the first visit of Sir Charles Lyell that the great beds of gypsum and limestone of Windsor, the Shubenacadie, and other places, with their associated sandstones and marls, were recognised as Lower Carboniferous. Even after Sir Charles had published his results, these were dissented from both by Logan and Gesner, though both these geologists subsequently convinced themselves, and admitted that they had been in error; and the latter even went so far as to believe that the red sandstones of Blomidon and Cornwallis were also Carboniferous. It then became a question whether there were really any rocks of the Triassic period in the province, and to determine this point, the writer undertook, in 1846, a careful examination of the red sandstone and trap on both sides of the bay, the results of which were published in the Proceedings of the Geological

Society of London.* In this paper, the relations of the New Red to the older formations in this province were for the first time accurately defined, by ascertaining its structure, and its actual superposition on Carboniferous strata, in the cliffs on the north side of Cobequid Bay and Minas Basin, and applying the facts thus obtained to the larger area of New Red on the south side of the bay, in the manner indicated by the following quotation :—

"It appears from the facts above stated, that the red sandstones of Cornwallis and Horton, though not seen in contact with the Carboniferous rocks, extend parallel to their disturbed strata with uniform north-west dips, and passing beyond them with the same dip, rest unconformably on the older slaty series. This arrangement, I think, satisfactorily proves that these red sandstones and the overlying trap are really newer than the Carboniferous shales of Horton, and unconformable to them."

"Eastward of the estuary of the Avon, the country as far as the Shubenacadie River is occupied by a deposit of reddish, gray, and purple sandstones and marls, with large beds of gypsum and limestones abounding in marine shells. This gypsiferous series is much fractured and disturbed, and is in many places associated with dark shales containing fossil plants, like those of Horton Bluff, and thin seams of coal. This association of the gypsiferous series with dark fossiliferous shales occurs at Halfway River, where coarse brown and gray sandstones, with imperfect casts of fossil trunks of trees, and a thick bed of anhydrite and common gypsum, rest conformably on the continuation of the dark beds of Horton Bluff. The carboniferous date of this gypsiferous series has been fully established by Mr (now Sir Charles) Lyell; and though it contains red sandstones with veins of gypsum like those of Blomidon, these never extend to so great a thickness as that of the Cornwallis sandstones, without alternating with fossiliferous shales or limestones, or with beds of gypsum. For this reason, in connexion with the undisturbed condition of the Cornwallis sandstones, their apparent unconformability to the Carboniferous shales of Horton, and their identity in mineral character and association with trappean rocks, with the red sandstones of Swan Creek and Five Islands, I have no hesitation in separating them from the gypsiferous series and including them in the New Red Sandstone formation."

From the same paper, I quote the following general statements as to the age and mode of formation of the New Red Sandstone and Trap, as affording in the most condensed form the conclusions at which I had then arrived :—

* Journal of Geological Society, iv. p. 50.

"I am not aware that any rocks equivalent in age to the red sandstones which have been described occur in any other part of Nova Scotia. Red sandstones, not unlike those of Cornwallis and Truro, occur in some parts of the newer Coal formation, as seen on the shores of the Gulf of St Lawrence; but they alternate with beds of shale and gray sandstone, containing fossil plants of carboniferous species. Prince Edward Island, in the Gulf of St Lawrence, is chiefly composed of soft red sandstones, little disturbed, and similar in mineral character to the New Red Sandstone of Nova Scotia; but they contain in their lower part silicified wood and other vegetable fossils, which are not unlike some of those found in the newer Coal formation. It is, however, probable that the greater part of these red sandstones of Prince Edward Island are post-carboniferous. It is also probable that the New Red Sandstone of Connecticut, and some other parts of the United States, which is believed to be a Triassic deposit, may be of the same age with the formation above described. At present, however, from the want of fossils in the New Red Sandstone of Nova Scotia, it must be regarded as a post-carboniferous deposit of uncertain age.

"The red sandstones now described appear to have been deposited in an arm of the sea, somewhat resembling in its general form the southern part of the present Bay of Fundy, but rather longer and wider. This ancient bay was bounded by disturbed Carboniferous and Silurian strata; and the detritus which it received was probably chiefly derived from the softer strata of the Carboniferous system. The arenaceous nature of the New Red Sandstone, as compared with the character of these older deposits, indicates that the ancient bay must have been traversed by currents, probably tidal like those of the modern bay, which washed away the argillaceous matter so as to prevent the accumulation of muddy sediment. When we consider the large amount of land in the vicinity of the waters in which the New Red Sandstone was deposited, the deficiency of organic remains in its beds is somewhat surprising, though this is perhaps to be attributed rather to the materials of the deposit and the mode of its accumulation, than to any deficiency of vegetable or animal life at the period in question.

"The volcanic action which manifested itself in the bed and on the margin of the bay of the New Red Sandstone is one of the most remarkable features of the period. It has brought to the surface great quantities of melted rock, without disturbing or altering the soft arenaceous beds through which it has been poured, and whose surface it has overflowed. The masses thus accumulated on the surface have greatly modified the features of the districts in which they occur; especially the great ridge extending westward from Cape Blomidon.

It is worthy of note, that this ridge, probably marking the site of a line of vents of the New Red Sandstone period, and occurring in a depression between two ancient hilly districts, so nearly coincides in direction with these older lines of disturbance. The trap rocks associated with the New Red Sandstone do not precisely coincide in mineral character with any that I have observed in other parts of Nova Scotia, though it is possible that some of the igneous rocks which have penetrated and disturbed the Carboniferous rocks of various parts of this province may belong to the New Red Sandstone period, or are of a date not long anterior to it."

The red sandstone formation affords fine loamy friable soils, especially adapted to the culture of fruit and of the potato. The red sandstone valleys of Annapolis and King's are celebrated for their apple orchards, which furnish large quantities of excellent fruit for exportation to the other parts of the colonies, and even to the United States and Great Britain. The same districts are well adapted to the growth of Indian corn, large quantities of which are annually produced; and in those years in which the potato has failed over nearly the whole of America, it has remained uninjured in the red sandy loams of Cornwallis, the farmers of which have in consequence realized large sums by supplying the markets of the New England states. The calcareous matter which serves as a cement to the sandstone, and the alkalis derived from the fragments of trap which have been scattered through the soil in the Drift period, add much to the fertility of these districts.

The agricultural capabilities of the trap are very different from those of the red sandstone. The soil, formed of decomposed trap, is very rich in the mineral ingredients most necessary to cultivated plants. It produces in its natural state a most luxuriant growth of timber, and yields excellent crops when recently reclaimed from the forest; but, perhaps from its porous and permeable texture, it is said not long to retain its fertility. I fear, however, that very bad methods of farming have generally been applied to it. The situation and exposure of the trap are singularly different from those of its contemporary the red sandstone. The latter usually appears in low and sheltered valleys. The trap, on the other hand, forms steep acclivities and high table-lands, exposed to the full force of the storms and changes of an extreme and variable climate; while its ranges of rugged cliffs, with their cascades, their terrible landslips, and the wild beating of the winds and waves upon their bare fronts, present nature in an aspect altogether different from that which she wears in the quiet valleys of the red sandstone. These differences are, even in this

new country, not without their influence on the mental and moral tone of the inhabitants of these dissimilar districts.

5. *Minerals of the New Red Sandstone and Trap.*

The red sandstone of this formation does not contain any valuable repositories of useful minerals. It frequently includes small veins of foliated and fibrous gypsum. In some parts of King's County it contains thin bands of impure limestone, and in one locality, near Cornwallis Bridge, I have observed in it a bed of impure manganese ore, a mineral which also occurs at Quaco. These deposits are, however, of too small dimensions to be of any practical value. The sandstone itself is usually too soft and perishable to form a useful building-stone. Blocks and slabs of it are, however, quarried for fire-places and chimneys, and are said to be well adapted to this use.

The trap contains some small veins of metallic minerals, not as yet known to be of mining importance; but it abounds in the finely crystallized minerals usually contained in the ancient volcanic rocks, and the long range of coast-line which it occupies, and the very rapid waste which it is undergoing, place these within reach of the collector in almost unexampled abundance. As these minerals are of much interest to mineralogists, and the trap formation of Nova Scotia has become somewhat celebrated for the abundance and fineness of the specimens which it affords, I give below a catalogue of the mineral species that I have collected, with references to the localities from which I have specimens in my cabinet, and which I believe to be the most productive of fine specimens. Many other localities, however, are mentioned by Messrs Jackson and Alger and Dr Gesner, who have devoted especial attention to these beautiful productions. I may remark, however, that interesting specimens may be found in almost all parts of the trap coasts, by inquiring for the spots in which land-slips have most recently occurred.

Magnetic Iron Ore—in octahedrons and massive; Partridge Island, North Mountains of King's.

Specular Iron Ore—in tabular crystals; Sandy Cove.

Native Copper—in irregular masses; Cape d'Or, Briar Island, and Peter's Point.

Gray Sulphuret of Copper, *Green Carbonate of Copper*, *Oxide of Copper*, associated with Magnetic Iron, at Indian Point, also Cape d'Or; not in fine specimens.

Quartz—occurs in a great variety of beautiful forms, among which

are Amethyst and Transparent Quartz in six-sided pyramids, Agate, Chalcedony, Carnelian, and Jasper. The best localities for these minerals are Blomidon, Scott's Bay, Digby Neck, and Partridge Island. A fine variety of Moss Agate occurs at the Two Islands, and a sort of Quartz Sinter in imperfect crystals and beautiful coralloidal forms in the neighbouring promontory of M'Kay's Head. Large quantities of fine Agates and Jaspers, applicable to ornamental purposes, may be found at Cape Blomidon and Digby Neck; and the Amethyst of the same localities is sometimes in sufficiently large crystals to admit of being cut for ring-stones, seals, etc.

Opal—occurs at a few localities, in the plain variety of semi-opal; and very frequently, in the form of white chalky Cacholong, forms the basis of fine crystallizations of amethyst, having lined the cavities of the trap before the latter was deposited.

Heulandite—Hydrous Silicate of Alumina and Lime, in fine rhombic prisms, colourless and light flesh colour, at Blomidon, Black Rock, Partridge Island, etc. Minute yellow crystals are found at Two Islands.

Stilbite—Hydrous Silicate of Alumina, Lime and Soda, or Potash, in radiated and sheaf-like aggregations of crystals of honey-yellow and brown colours, at Partridge Island, Sandy Cove, Blomidon, Black Rock, etc. Fine groups of white crystals are found at Black Rock in King's County and its vicinity.

Mesotype.—The variety or species *Natrolite*, the Hydrous Silicate of Alumina and Soda, is found in small prismatic crystals and in radiated masses of crystals, at Blomidon, Two Islands, M'Kay's Head, Scott's Bay, etc. The variety *Scolecite*, or Hydrous Silicate of Alumina and Lime, is found at the same localities, also in radiating and prismatic forms. The variety *Mesolite*, or lime and soda Mesotype, is also found at various localities.

Laumonite—Hydrous Silicate of Alumina and Lime, in whitish and light red prismatic crystals, at Peter's Point, Black Rock, Sandy Cove, etc. This mineral, very beautiful when freshly taken from the rock, loses water and becomes opaque and brittle when exposed to air and light. I have found that this change takes place very rapidly when the specimens are exposed to sunlight, and is much retarded by keeping them in darkness. Immersion in gum-water is also a preventive.

Chabazite—Hydrous Silicate of Alumina, Lime, Soda, and Potash. The flesh red, brownish red, purplish red, and yellowish red

varieties, which have been named *Acadiolite*, are found abundantly at Two Islands in trap conglomerate. Their red colour is due to the peroxide of iron which abounds in the cement of the conglomerate and the neighbouring red sandstone. Grayish and white varieties are found at the same place, also at Cape d'Or and Digby Neck. The usual form is the primary rhombohedron; the six-sided pyramid occurs rarely at Cape Blomidon. According to Marsh, the variety Gmelinite is found at Blomidon.

Analcime—Hydrous Silicate of Alumina, Soda, and Lime. Trapezohedrons of white and dull reddish colours occur at Blomidon, Two Islands, M'Kay's Head, etc.

Thomsonite—Hydrous Silicate of Alumina, Lime, and Soda or Potash. I have a small specimen in radiating crystals from the North Mountains of King's County.

Prehnite—Hydrous Silicate of Alumina, Lime, and Iron. Recorded by Gesner as found at Black Rock. I have not seen it.

Apophyllite—Hydrous Silicate of Lime and Potash is found at a number of places, but in none very plentifully. Green and white crystals, aggregated in plates or in square prisms, occur at Blomidon, Peter's Point, Two Islands, and Cape d'Or. The finest specimens that I have seen are from the latter place, and present rosette-shaped groups of crystals. They were collected by the late Professor Chipman of Acadia College, and are now, I believe, in the museum of that institution.

Calcareous Spar—Carbonate of Lime is found in fine rhombohedral crystals of white and yellowish colours, and also in the imperfect scalenohedrons known as Dogtooth spar, at Partridge Island, Black Rock, Two Islands, etc.

To the above list I may add *Faroelite*, a mineral allied to Scolecite, discovered by Prof. How at Port George, and mentioned by Marsh as occurring at Cape d'Or and Blomidon.* Prof. How has also noticed *Gyrolite* as occurring in Apophyllite near Cape Blomidon,† and has described *Centrallasite*, *Cerinite*, *Cyanolite*, and *Mordenite*, from the Trap of Nova Scotia.‡

* Silliman's Journal, N. S., xxvi. p. 31, and vol. xxxv. p. 215.

† *Ibid.*, vol. xxxii.

‡ Ed. Phil. Journal, x. 84, Qu. Journ. Chem. Soc., 1864.

CHAPTER VIII.

THE TRIAS OR NEW RED SANDSTONE—*Continued.*

PRINCE EDWARD ISLAND—AGE OF ITS SANDSTONES—FOSSIL PLANTS—REPTILIAN REMAINS—USEFUL MINERALS AND SOIL.

Prince Edward Island, which stretches for 125 miles along the northern coast of Nova Scotia and New Brunswick, has everywhere a low and undulating surface, and consists almost entirely of soft red sandstone and arenaceous shale, much resembling the New Red of Nova Scotia, and like it having the component particles of the rock united by a calcareous cement. In some places the calcareous matter has been in sufficient abundance to form bands of impure limestone, usually thin and arenaceous. Over the greater part of the island these beds dip at small angles to the northward, with, however, large undulations to the south, which probably cause the same beds to be repeated in the sections on the opposite sides of the island. This is the general character of the island in all parts of it that I have explored, with the exception of a few limited spots on the south side, which present brown and gray sandstones and shales, not unlike some of the upper parts of the Coal Formation of Nova Scotia, and containing a few fossil plants. These are apparently the lowest and oldest beds observed, and they may possibly belong to a series underlying unconformably the ordinary red sandstone of the island. The determination of their true geological age is important, as affording data for ascertaining that of the red sandstone. I shall therefore give a somewhat detailed account of these beds as they appear at Orwell or Gallows Point on the south coast, about ten miles east of Charlottetown.

In approaching this place, the red sandstone forms long undulations sloping gently toward the shore, and the coast displays a series of low points, terminated by red sandstones, which, though not hard, have better resisted the wearing action of the waves than the softer strata which have occupied the intermediate creeks. Passing through Cherry Valley, the country has the same appearance until we enter

the by-road to Orwell or Gallows Point, when the soil loses its bright red colour, and assumes a grayish tint, and more argillaceous composition, indicating to the geological traveller a change in the composition of the rocks beneath. On reaching the extremity of the Cape, a good section of a considerable variety of rocks may be seen. Their dip is to the E. S. E. by compass (variation about 19 deg. W.), at an angle of only 6 degrees; consequently in proceeding along the shore to the westward, lower and older rocks appear cropping out from beneath those which overlie them. Commencing with those which are higher in order, red and brown sandstones, of soft and rather coarse texture, occupy a considerable portion of the shore, projecting in low reefs into the sea, and rising to the height of a few yards in a water-worn cliff. Beneath these appear harder gray sandstones, containing gray and brown impure limestone, in beds a few inches in thickness. One of these beds contains a number of fragments of fossil plants, in a very imperfect state of preservation. Beneath these strata is a bed of sandstone, containing small nodules of red ochre, and in one place the impression of a large fossil tree, whose wood has disappeared, leaving a mould which has been filled with ochreous clay. Proceeding in the same direction, we find beds of considerable thickness consisting of gray and brown clay, apparently without coal or fossils. Beneath these are several beds of brownish sandstone of various qualities, one stratum appearing to be sufficiently hard for building purposes. Embedded in one of these layers appear some large fossil trees, one of them nearly three feet in diameter; they are prostrate and much flattened by pressure, and the place once occupied by their wood is now filled with a hard dark-coloured silicious stone, which, when polished in thin slices, and examined by the microscope, displays the structure of the original wood. These trees appear to have been partially decomposed before they were submitted to the petrifying process, and the rents caused by decay are now filled with red-coloured crystals of sulphate of barytes. In some of the specimens the fissures are coated with silicious crystals, and portions of some of the trunks consist of a soft carbonaceous ironstone retaining the woody structure. These fossil trees carry back our thoughts to a period when Prince Edward Island was a tract of submarine sand, in which drift trees were embedded and preserved, and which has since been indurated and partially elevated above the level of the sea. In another of these sandstone beds are the remains of a large tree compressed to the thickness of an inch, and converted into friable shining coal, coloured in some places with green carbonate of copper.

These beds must belong either to the very newest portions of the

Coal Formation, which in some particulars they closely resemble, or to the lower part of the New Red Sandstone; and in either case the sandstones of the greater part of Prince Edward Island will be New Red. Unfortunately I could not observe whether the latter are superimposed conformably or unconformably on the lower beds, and the fossils are hardly sufficiently well characterized to indicate to which epoch they belong. With the view of obtaining from them all the information they are capable of affording, I have examined the fossil wood of this locality, and some specimens found lying loose on the surface at Des Sables and other places in the island, with the following results:—

Thin slices of the specimens from Orwell Point show under the microscope in the transverse direction a dense tissue of quadrangular cells, arranged in rows, with numerous but narrow medullary rays. Longitudinal slices in the direction of the medullary rays show elongated parallel cells, with traces of hexagonal discs on the walls of the cells, there being two or more rows of discs in each cell, though these structures are not very distinct. These characters are those of coniferous wood (that of the pine tribe), and of that particular type of coniferous trees which appears in the northern hemisphere only in the Palæozoic and Mesozoic rocks. The specimens from other parts of Prince Edward Island show similar structures, some of them even more distinctly.

In so far as I can make it out, the structure is that of the genus *Dadoxylon*, and approaches to that of *D. materiarium*, the most common fossil pine of the Upper Coal Formation in Nova Scotia. The evidence of this fossil wood thus tends to indicate an older geological period than that of the New Red Sandstone,—assuming the latter to be of Triassic age,—and would give some countenance to the belief that these beds of the south coast of Prince Edward Island at Des Sables and Gallows Point, if not Permian, may represent the upper beds of the Newer Coal Formation, to which, as they appear in Eastern Nova Scotia, these rocks bear considerable resemblance. The beds of the Newer Coal Formation in Eastern Nova Scotia are usually only slightly inclined, and are arranged in flat synclinals and anticlinals. It is quite possible that one of the latter crossing the strait may appear rising from under the New Red Sandstone. This view, if established, would be of importance in answering the question whether coal is likely to be found in Prince Edward Island, a question to which we may return in the sequel. Whatever the age of these beds, they are probably the oldest known in the island, and the red sandstones resting on them may be assumed to be Triassic.

A very interesting fossil, which greatly aids in fixing this geological age for the red sandstones of Prince Edward Island, has recently been discovered. It is a portion of the jaw of a large *carnivorous reptile*, apparently closely allied to the *Thecodontosaurus* of the English New Red Sandstone. This creature must have rivalled in dimensions the modern alligators, but must have belonged to a different group of reptiles, represented in the present world only by lizards of moderate or small dimensions. It was, in short, one of that giant *reptile aristocracy* which constituted the dominant animal type in the Middle or Secondary period of geological time, which in consequence has long been known as the peculiar "age of reptiles."

The specimen was found by Mr D. M'Leod of New London, on the north side of the island, in the bottom of a well, at the depth of twenty-one feet nine inches, and imbedded in the ordinary soft red sandstone of that part of the island. The discoverer was desirous of disposing of the specimen; and the writer being convinced that it would prove of great interest to naturalists, if examined and described by a competent anatomist, offered to negotiate its sale. By the advice of Sir Charles Lyell, then in America, it was offered to the Academy of Natural Sciences, Philadelphia; for which it was finally purchased for the sum of thirty dollars. It was described and figured in the Proceedings of the Society by Dr Leidy, from whose elaborate paper I extract the following description, which, with the aid of Fig. 29, will serve to give some idea of its character:—

Fig. 29.—*Outline of Jaw of Bathygnathus borealis,—reduced.*

(*a*) Cross section of second Tooth, nat. size. (*b*) Fifth Tooth, nat. size.

"The specimen consists of the right dental bone, considerably broken, attached by its inner surface to a mass of matrix of a red granular sandstone, with large, soft angular red chalk-like stones

imbedded in it.* The fossil has seven large teeth protruding beyond the alveolar margin of the jaw; and it is hard, brittle, and cream-coloured, and stands out in beautiful relief from its dark-red matrix. The jaw indicates a lacertian reptile, and, in comparison with that of other known extinct and recent genera, is remarkable for its great depth in relation to its length.

"The depth of the dental bone is five inches, whilst its length in the perfect condition appears not to have exceeded seven and a quarter inches; for in the specimen the middle part of the posterior border is so thin and scale-like, that I am disposed to think it here came in contact with the supra-angular and other neighbouring bones.

"The teeth, in their relation to the dental bone, are placed on the inner side, and rest against the alveolar border, which rises in a parapet external to them. Whether this parapet is supported by abutments between the teeth, as in *Megalosaurus*, I cannot clearly ascertain, from the inner side of the jaw being so closely adherent to the matrix. The dental bone, if it be considered complete in its length in the specimen, is capable of containing a series of twelve teeth.

"As the teeth were worn away or broken off, they were replaced by others produced at their inner side, as is indicated in the specimen by a young tooth, which is situated internal to, and is concealed by, the largest mature tooth. The enamelled crowns of the fully protruded teeth are exserted at their base for several lines above the alveolar border of the jaw. They are compressed, conoidal, and recurved; but compared with those of *Megalosaurus* they are not so broad, compressed, nor recurved, and they are more convex externally, and are less so internally. They resemble much in form those of the recent *Monitor ornatus*, but are less convex internally. The anterior and posterior acute margins of the crowns are minutely crenulated; and the crenulations commence just below the tip, and descend as far as the enamelled base."

Dr Leidy then proceeds to describe the teeth minutely, remarking that the first in the series is narrow, and not crenulated, and that it is separated from the second by a space sufficiently large to have held another tooth. "The second tooth seen in the figure is the largest and longest of the series; and its enamelled crown, when perfect, was about an inch and three quarters long by seven lines in breadth at the base. Its fang can be seen in the wide fissure of the jaw, descending two inches from the alveolar border; and, being broken, it is observed to be hollow as far as the enamelled crown." The third tooth has not fully protruded, and the fourth, fifth, and sixth, have nearly the

* These are probably concretions.—J. W. D.

same size and form, and are highly perfect piercing and cutting instruments, with sharp and finely crenulated edges. The space between the fourth and fifth tooth is sufficient to contain one additional tooth, and that between the sixth and seventh is sufficient for two, and has in it a young tooth just appearing above the jaw. There is an impression of an eighth tooth on the matrix. The whole jaw may thus, when perfectly filled, have accommodated twelve teeth on each side of the mouth; in predaceous reptiles, however, the teeth are often broken and are renewed, so that in adult animals they are never uniform or complete.

From the extraordinary depth of the dental bone relatively to its length, and from its northern locality, Dr Leidy has named the animal to which it belonged *Bathygnathus borealis*. He adds: "This interesting fossil is the second authentic discovery of saurian bones in the New Red Sandstone of North America; the first being those found near Hossac's Creek, in Lehigh county, Pennsylvania, by Dr Joel Y. Shelley, and described by my friend Mr Isaac Lea, under the name of *Clepsysaurus Pennsylvanicus*."

The remains of this ancient reptile must have been drifted by the sea, and embedded in the sand now forming the red sandstone of New London. Probably its bones, after the decay of the body, were scattered over the bottom, to be buried under the next layers of sand spread over it. What information can we derive from the fragment which has been handed down to our time, respecting the structure and habits of the creature, and the age of the rock in which it was embedded? The teeth prove decisively that the animal to which they belonged was fitted for capturing and devouring other animals. It is difficult to imagine an instrument better fitted for cutting and tearing asunder than a jaw furnished with these sharp and serrated teeth. The size of the teeth, and the shortness and depth of the jaw, indicate an amount of power sufficient for the destruction of large animals, perhaps fishes, smaller reptiles, or even clumsy and gigantic wading birds, all of which are known to have existed as far back as the New Red period. Among living carnivorous reptiles, those which, like the crocodile, are clumsy and less agile in their movements, have elongated snouts to enable them the more easily to secure their prey; those which, like the serpents, can move with extreme rapidity, have comparatively short jaws. We may therefore infer that this creature was furnished with means of very rapid movement, either on land or water. It could spring or dart on its prey. If we had the remains of its extremities, we could determine what its means of movement were, and whether the sea or the land was its sphere of

activity. Without these nothing very certain can be determined on these subjects. The apparent thinness and density of the bone, however, and its width of surface, convey the impression that it was intended to combine great strength with great lightness, and therefore that it belonged to a creature of terrestrial habits. Probably considerations of this kind, though he does not state his reasons, induced Dr Leidy to hazard the conjecture, "Was this animal probably not one of the bipeds which made the so-called bird-tracks of the New Red Sandstone of the valley of the Connecticut?" This conjecture of an eminent anatomist, itself shows how singular and anomalous among reptiles is this fossil fragment.

Had this fossil been specifically identical with any reptile whose remains have been found in other countries the age of whose rocks has been determined, it might have given conclusive evidence as to the true geological age of the red sandstones of New London. It is, however, a new species of a new genus, quite distinct therefore from any species found elsewhere. Still it gives some important testimony. It belongs to a group of large and highly organized carnivorous reptiles now extinct, and which occupied in the Secondary period of geology a place afterwards taken by the carnivorous mammalia. No reptiles of equal grandeur and perfection have existed since the beginning of the Tertiary period; and so far as we know, none were created before the very close of the Palæozoic period. Between these eras, therefore, we may place our fossil; but this gives a very wide range. There is, however, a difference of *facies* or general appearance between the reptiles of different parts of this long reptilian dynasty, which enables us to distinguish between them, just as an antiquary might distinguish a coat of armour of the time of John of Gaunt from one of the time of Henry the Seventh. Now, as already hinted, the reptile in question appears to have most nearly resembled the *Thecodontosaurus* and *Palæosaurus*, reptiles of the Triassic system of England, than any other known animals; hence it confirms the view generally adopted on other grounds, that this is the age of the Prince Edward Island New Red, and its corresponding formation in Nova Scotia. At the time when the first edition of this work was published, it was held by British geologists that the dolomitic conglomerates of Bristol, in which the remains of the two saurians above named are found, belonged to the *Permian* period; and I stated accordingly that the affinities of *Bathygnathus* seemed to be with reptiles of that period. More lately, however, the officers of the Geological Survey of Great Britain have satisfied themselves that the beds in question belong to the Trias.

The red sandstone of Prince Edward Island is not known to contain any useful minerals except limestone, which occurs in thin beds in several places. Indications, apparently of no economic value, of ores of copper and manganese occur in a few places. The red sandstone everywhere supports a fine, friable, loose, loamy soil, which renders Prince Edward Island one of the finest agricultural districts in the lower provinces—a distinction which well compensates the want of valuable minerals. I have not observed, in any of my excursions in the island, any traces of igneous action; but Dr Gesner, in the report of a survey undertaken for the provincial Government, mentions the occurrence of a limited mass or dike of trap on Hog Island, an isolated spot which I have not visited, in Richmond Bay; and which I have accordingly coloured in the map with the tint appropriate to that rock. This fact, though not of any importance in establishing the age of the formation, affords an additional analogy between it and the New Red of Nova Scotia.

The question of the possible occurrence of coal in Prince Edward Island has always been of much interest to its inhabitants, and I believe that a grant of money has been made by the Legislature to promote boring in search of mineral fuel. In answer to this question, it may be stated, in the first place, that since the rocks of Prince Edward Island, or the greater part of them, are certainly newer than the Coal Formation, there is a reasonable probability that the coal-measures exist under the island. On the other hand, the New Red Sandstone being of considerable thickness, and the upper unproductive coal formation of Nova Scotia being also of great thickness, it is probable that such coal-beds as may exist under Prince Edward Island are at a very great depth. Again, it is very obvious that, if boring operations are to be undertaken, the chances of success would be very different in different parts of the island. Toward the north side the whole thickness of the red sandstone would have to be bored through, probably to the extent of several hundreds of feet, before reaching even the Upper Coal Formation. On the other hand, at those places on the south side where fossil plants occur, it is even possible, as above stated, that the upper beds of the Newer Coal Formation actually crop out from beneath the red sandstone. In this case the chances would be much better; but since the Upper Coal Formation of Pictou, without productive coals, is estimated at about 3000 feet in thickness, the valuable coals would still be out of reach, unless this upper member should prove thinner than on the mainland, of which we have as yet no evidence.

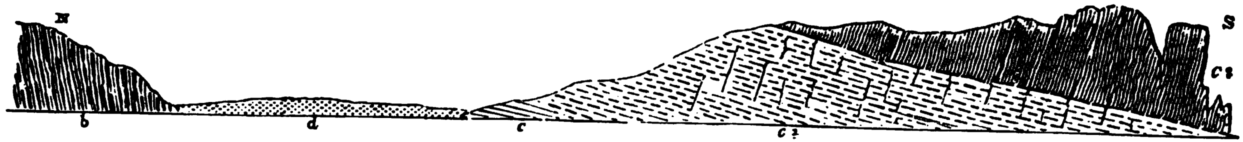
The question would be complicated by supposing the possible

unconformability of the New Red Sandstone and Coal Formation; but as the dips of the latter are very low on the Nova Scotia and New Brunswick shore, it is probable that the two formations are conformable, or very nearly so.

On the whole, though I would scarcely venture to advise the expenditure of any large sum in boring for coal in Prince Edward Island, I would say that, should it be determined to incur such expenditure, the most promising places at present known to me are in the vicinity of Orwell Point and of Des Sables. Boring in these places would at least afford the satisfaction of knowing what underlies the red sandstone, and whether any chance exists of the discovery of coal under it. It is proper to state, however, that I have not explored the south shore of the island very extensively, and that there seems no good reason why equally favourable localities might not exist at Bedeque or at Wood Islands, or at other localities west and east of these places. Careful preliminary exploration of every place supposed to be promising should be made by some competent person familiar with the structure of the Upper Coal Formation in Nova Scotia or New Brunswick, before incurring any expense in boring.

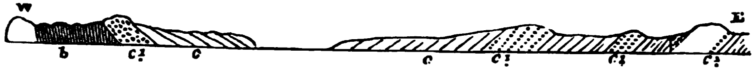
In a MS. section of the north coast of New Brunswick by the late Professor Robb, he indicates at the extremity of Cape Tormentin a small patch of red micaceous sandstone overlaid by red marly rock, and dipping to the east at an angle of 15°. This I regard as very probably an outlier of the red sandstone of Prince Edward Island; and, if so, it affords the only known point of contact of this formation with the Carboniferous rocks of the mainland. I have only seen Cape Tormentin from the sea, and therefore cannot speak distinctly of the nature of the junction; but the red rocks probably rest unconformably on the end of an anticlinal undulation of the coal formation. Were I about to make a geological survey of Prince Edward Island, I would make these rocks of Cape Tormentin one of my first studies, and would consider myself fortunate if I could establish their claim to be considered, in a geological point of view, a portion of Prince Edward Island.

JUNCTIONS OF FORMATIONS.



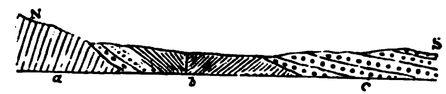
Partridge Island.

b, Carboniferous. *c*, Trias. c^1, Tufaceous Trap. c^2, Basaltic Trap. *d*, Modern Gravel.



Near Swan Creek.

Letters as on Section above.



Great Village River.

a, Silurian.* *b*, Carboniferous. *c*, Trias.

Near M'Cara's Brook, Pictou County.

a, Arisaig Series, Silurian. *b*, Carboniferous Conglomerate and Sandstone. b^1, Interstratified Trap. b^2, Carboniferous Limestone.

Cobequid Bay to Cobequid Mountains.—Line of Folly and Debert Rivers.

a, Silurian.* *b*, Carboniferous. *c*, Trias.

* These beds should have been represented as dipping to the South.

CHAPTER IX.

THE PERMIAN BLANK.

ONE whole period of the earth's Palæozoic history appears to be represented by no monuments in Acadia. The base of the Trias everywhere rests unconformably on the upturned beds of the Carboniferous, and the *Permian* system, represented in England by the great magnesian limestone and its associated beds, and in Germany by the Zechstein and the sandstones and shales above and below it, is absent from our series of formations. The same gap occurs, in so far as known, throughout Eastern North America. It is only west of the Mississippi, in Kansas, and on the eastern slope of the Rocky Mountains, that the Permian beds have been recognised. There they consist of limestones, sandstones, marls, and conglomerates, with beds of gypsum resting conformably on the Carboniferous beds, and separating them from the Trias. Their fossils are closely allied to those of the Upper Coal Formation, and very different from those of the Trias,—the latter constituting the beginning of the great *Mesozoic* division of geological time, the former the close of the *Palæozoic*.

The lapse of time represented by these Permian beds, and which, though probably shorter than the Carboniferous period, must have been of long duration, is indicated in Acadia only by the disturbances which the Carboniferous beds have suffered before the deposition of those of the Trias, unless we can regard any portion of the great series of beds which I have named the Upper Coal Formation as equivalent in time to the Permian.

It may be well shortly to inquire if we can bridge over this vacant space by any considerations based on the well-known systems of formations which constitute its boundaries. We have here first the well-established fact, that the long and quiet period of the Coal Formation was succeeded in Eastern America by an epoch of physical disturbance, in which the Carboniferous rocks were greatly tilted and contorted, and in many places subjected to more or less alteration. The time occupied by these processes we cannot precisely measure;

but there is every reason to believe that it was of long duration. Again, in connection with this, the relations of the Trias to the Carboniferous show that the latter must have experienced much denudation by aqueous agency prior to the deposition of the former. Lastly, the study of the distribution of the Trias over the shores of the Bay of Fundy shows, as already stated, that, previous to the Triassic period, that Bay had already assumed in some measure of its present form, and, consequently, that the Carboniferous beds had already in part been elevated into land. All these facts give us evidence of lapse of time—of time occupied in this locality not by aqueous deposition, but by physical movements, probably of elevation, and by denuding action. That this time corresponded to that of the Permian elsewhere, no one who believes in the contemporaneousness of the Carboniferous of America with that of Europe can doubt. The possibility, however, still remains that Permian beds may have been deposited in some parts of the area, and may have been removed by denudation, or may be covered by the Trias or by the sea. This is, however, only a mere possibility, so long as no traces of these beds can be discovered.

Again, it is possible that the conditions of the Upper Coal Formation may have continued longer in America than in Europe, and, consequently, that this part of the Carboniferous may synchronize with the Permian of Europe and with that of Western America. This raises the question of "Homotaxis," as it has been called, or similarity of arrangement as distinguished from actual contemporaneity. An able palæontologist has said that, "for anything that geology or palæontology can show to the contrary, a Devonian flora and fauna in the British Islands may have been contemporaneous with Silurian life in North America, and with a Carboniferous fauna and flora in Africa. Geographical provinces and zones may have been as distinctly marked in the Palæozoic epoch as at present." I must maintain, however, that no such uncertainty exists as to the Carboniferous period. In America, its flora was homogeneous from Newfoundland to Alabama, and from the Atlantic Coast to the Rocky Mountains, evidencing a uniformity of climate unparalleled in modern times. Its succession of zones of vegetation, from that of the lower coal-measures upward, is preserved over all this area; and when we find it existing in all its detail in Europe, and with a majority of the species the same, it would be most rash to suppose that the times of this succession were not identical. Farther, it seems impossible to doubt that this uniformity was caused by prevalent climatal conditions which could not have been local; as, for instance, by a

different distribution of land and water, as supposed by Sir Charles Lyell, and by a larger proportion of carbonic acid in the atmosphere, as suggested by Tyndall and Hunt. For these reasons, and others to which I shall refer in a succeeding chapter, there is no room left for homotaxis, as distinguished from contemporaneity, in the case of the Carboniferous; and if so, there can be little in that of the Trias. The Permian was thus a real period in Eastern America, but a period without extant monuments, except those which relate to merely mechanical movements of the sediments previously formed,—a period of breaking down, not of building up.

Still the Permian in Eastern America must have been a time of life and activity. If, as seems most probable, this country was, at the close of the Carboniferous period, raised up to a height somewhat similar to that of the continent in the present day, this Permian land must have been inhabited by plants and animals. We can imagine it clothed with a flora similar to that of the European Permian, and inhabited by the Protorosaurs and other animal forms of the period, and we can imagine those changes going on by which the Palæozoic flora and fauna were replaced by those of the Mesozoic period. In the singular little deposit of Miocene plants at Brandon in Vermont, we have evidence that this was the case in those Tertiary periods of which, as already stated, we have no formations in Acadia; and perhaps there may yet be found some patch of Permian rock, formed in some lake or estuary, which may reveal to us the history of this as yet unrecorded passage in the geological history of our country.

CHAPTER X.

THE CARBONIFEROUS SYSTEM.

GENERAL REMARKS—SYNOPTICAL TABLE—GEOGRAPHICAL ARRANGEMENT—CARBONIFEROUS DISTRICT OF CUMBERLAND—SOUTH JOGGINS SECTION.

I HAVE had frequent occasion to state that the lower beds of the Triassic sandstones rest on the edges of the upturned strata of the great geological series now to be described. In entering, therefore, on the Carboniferous system, we go at least one whole period back in the history of the earth, to a time when the rocks that formed the shore of the red sandstone sea were themselves being deposited in the form of sediment, in waters which washed the sides of the Cobequid Hills and the other old metamorphic ranges.

The Carboniferous system is of inestimable importance in an economical point of view, from the number and value of its useful minerals. It is also of exceeding interest to the geologist, in consequence of the many remarkable monuments which it contains of the changes of the earth's surface, and of the character of its inhabitants, during a long and important period. None of the geological formations surpasses it in either of these respects; and in Nova Scotia and the neighbouring colonies there is none which approaches to an equality with it. It is also a very thick group of beds, and these are very varied in their character. For these reasons, I shall commence my description with a synoptical view of its various members, as they have now been ascertained in Nova Scotia. An examination of this condensed summary will enable the reader much more clearly to comprehend the statements hereafter to be made.

Physical Characters and Subdivisions of the Carboniferous.

The total vertical thickness of the immense mass of sediment constituting the Carboniferous system in Nova Scotia may be estimated from the fact that Sir W. E. Logan has ascertained, by actual measurement at the Joggins, a thickness of 14,570 feet; and this does not include the

lowest member of the series, which, if developed and exposed in that locality, would raise the aggregate to at least 16,000 feet. It is certain, however, that the thickness is very variable, and that in some districts particular members of the series are wanting, or are only slenderly developed. Still the section at the Joggins is by no means an exceptional one, since I have been obliged to assign to the Carboniferous deposits of Pictou, on the evidence of the sections exposed in that district, a thickness of about 16,000 feet; and Mr R. Brown of Sydney has estimated the Coal formation of Cape Breton, exclusive of the Lower Carboniferous, at 10,000 feet in thickness.

When fully developed, the whole Carboniferous series may be arranged in the following subordinate groups or formations, the limits of which are, however, in most cases not clearly defined:—

(1.) *The Upper Coal Formation*, containing coal formation plants, but not productive coals.

(2.) *The Middle Coal Formation*, or coal formation proper, containing the productive coal-beds.

(3.) *The Millstone-grit Series*, represented in Nova Scotia by red and gray sandstone, shale, and conglomerate, with a few fossil plants and thin coal seams, not productive.

(4.) *The Carboniferous Limestone*, with the associated sandstones, marls, gypsum, etc., and holding marine fossils, recognised by all palæontologists who have examined them as carboniferous.

(5.) *The Lower Coal Measures*, holding some, but not all, of the fossils of the Middle Coal formation, and thin coals, not productive; but differing both in flora and fauna from the Upper Devonian, which they overlie unconformably.

In regard to their mineral character, thickness, organic remains, and geographical distribution, these several formations may be described as follows:—*

(*a.*) *The Upper Coal Formation.*—Consists of sandstones, shales, and conglomerates, with a few thin beds of limestone and coal. *Calamites Suckovii*, *Annularia galioides*, *Cordaites simplex*, *Alethopteris nervosa*, *Pecopteris arborescens*, *Dadoxylon materiarium*, *Lepidophloios parvus*, and *Sigillaria scutellata*, are among its characteristic vegetable fossils. Its thickness is 3000 feet or more; and its shales and sand-

* If the reader should, in glancing at these descriptions, or at the succeeding sectional list, meet with technical terms not familiar to him, he will find their explanation farther on, in the chapters and notes relating to Carboniferous fossils. Descriptions of genera and species may be referred to by looking up their names in the index, where the numbers of the pages in which they are described or figured will be indicated.

stones are frequently reddened by the peroxide of iron, though usually not of so bright a red as the New Red Sandstone, and always alternating, at short intervals, with gray beds. It occupies a considerable breadth in the county of Cumberland north of the Cobequid Mountains, in Northern Colchester, and in Pictou. It is well exposed on the Joggins coast, and on the coast of Northumberland Strait west of Pictou Harbour.

(*b.*) *The Middle Coal Formation*, or coal measures proper.—This series includes the productive beds of coal, and is destitute of properly marine limestones. Beds tinged with peroxide of iron are less common in this formation than in any of the others. Dark-coloured shales and gray sandstones prevail, and there are no conglomerates. *Sigillariæ* and *Stigmariæ* of many species are the most conspicuous and abundant fossils; but ferns, *Cordaites*, and *Calamites* are also extremely abundant, and all the genera of Carboniferous plants are represented. Many beds, especially those in the vicinity of layers of coal, contain minute *Entomostraca*, shells of the genus *Anthracomya* (*Naiadites*), *Spirorbis carbonarius*, and remains of ganoid and placoid fishes.

The thickness of this formation may be estimated at 4000 feet. It is largely developed in Cumberland, Pictou, and the eastern and western sides of the island of Cape Breton, and it occupies a great breadth in New Brunswick.

(*c.*) *The "Millstone-grit" Formation.*—This name, though not in all cases lithologically appropriate, has been borrowed from English geology to designate the group of sandstones, shales, and conglomerates, destitute of coal, or nearly so, and with few fossil plants, which underlies the coal measures. In its upper and middle part it includes thick beds of coarse gray sandstone holding prostrate trunks of coniferous trees (*Dadoxylon Acadianum*). In its lower part, red and comparatively soft beds prevail. This formation is exposed in the same localities mentioned above for the Middle Coal formation, and especially in the south Joggins section, where it attains to the enormous thickness of between 5000 and 6000 feet.

(*d.*) *The Lower Carboniferous Marine Formation.*—The essential features of this formation are thick beds of marine limestone, characterized principally by numerous brachiopods, especially *Productus Cora*, *P. semireticulatus*, *Athyris subtilita*, and *Terebratula sufflata*,* with other marine invertebrates. Associated with these limestones are beds of gypsum, and they are enclosed in thick deposits of sandstone, clay, and marl, of prevailing red colours.

* See Davidson "On Lower Carboniferous Brachiopoda from Nova Scotia," Quart. Journ. Geol. Soc., vol. xix. p. 158.

The thickness of this formation seems to be very variable, and in some districts it is represented almost entirely by conglomerates, while in others it abounds in limestone and gypsum. It is very largely developed in Hants and Colchester counties, and rises from beneath the Millstone-grit in Cumberland, Pictou, and Cape Breton. Smaller areas occur in several other parts of the province of Nova Scotia, and it is extensively developed in New Brunswick. It affords all the gypsum exported from Nova Scotia and New Brunswick.

(*e.*) *The Lower Carboniferous Coal Measures, or Lower Coal Measures.*—In some localities these resemble in mineral character the true coal measures. In others they present a great thickness of peculiar bituminous and calcareous shales. They usually contain in their lower part thick beds of conglomerate and coarse sandstone, which in some places prevail to the exclusion of the finer beds. The characteristic plants of these beds are *Lepidodendron corrugatum* and *Cyclopteris Acadica*, with *Dadoxylon antiquius*, and *Alethopteris heterophylla.** They also contain locally great quantities of remains of fishes, and many Entomostracans, among which are *Leaia Leidyi* and an *Estheria*, also *Leperditia subrecta*, Portlock, *Beyrichia colliculus*, Eichw., and a *Cythere*,† probably new.

This formation is not everywhere distinguishable at the base of the Carboniferous, and is variable in its characters. It is seen in southern Cape Breton, in the county of Sydney, and in Hants; but its most remarkable and interesting exposures are at Horton Bluff and at Hillsborough, and other places in southern New Brunswick. In the last-mentioned locality, it affords the remarkable bituminous mineral known as Albertite.

The last two groups are probably equivalent to the "Sub-carboniferous" of Western geologists; but independently of the objection to the use of a term which would seem to imply a formation under, and distinct from, the Carboniferous, and of undetermined age, I find in Nova Scotia no reason, either palæontological or stratigraphical, for any greater distinction than that implied in the term *Lower Carboniferous*, by which these groups will collectively be designated in this volume. The Lower Coal measures are, it is true, more distinct in their flora from the Middle Coal measures than the latter from the Upper Coal formation; but still many species are common to the two former, and the difference is small as compared with that between the Lower Carboniferous and the Upper Devonian. The Devonian

* Dawson, "On the Lower Coal Measures," etc., Quart. Journ. Geol. Soc., vol. xv. p. 62.

† Prof. Jones of Sandhurst has kindly determined these species.

rocks are also in this region unconformable to the Carboniferous, having been disturbed and altered prior to the deposition of the latter; while no want of conformity, except of the local character hereafter to be noticed, occurs in the Carboniferous. Geinitz has shown ("Isis," 1866) that my lower, middle, and upper coal formations are equivalent to three of the zones into which he divides the coal formations of Saxony.

Conditions of Deposition of the Beds.

It is evident that very various geographical conditions are implied in the deposit of this vast thickness of sediment. The Acadia of the Carboniferous period must not only have differed much from that which now is, but it must have presented very different appearances in the different portions of the Carboniferous time itself.

The conditions of deposit thus implied in the mineral character and fossils of the several formations above described, would appear to be of three leading kinds:—(1.) The deposition of coarse sediment in shallow water, with local changes leading to the alternation of clay, sand, and gravel. This predominates at the beginning of the period, recurs after the deposition of the marine limestones in the formation of the "Millstone-grit," and again prevails in the upper coal formation. (2.) The growth of corals and shell-fish in deep clear water, along with the precipitation of crystalline limestone and gypsum. These conditions occurred during the formation of the Lower Carboniferous limestone and its associated gypsum. (3.) The deposition of fine sediment, and the accumulation of vegetable matter in beds of coal and carbonaceous and bituminous shale, and of mixed vegetable and animal matters in the beds of bituminous limestone and calcareo-bituminous shale. These conditions were those of the middle coal formation.

Within the limits of Nova Scotia, these conditions of deposition applied, not to a wide and uninterrupted space, but to an area limited and traversed by bands of Silurian and Devonian rocks, already partially metamorphosed and elevated above the sea, and along the margins of which igneous action still continued, as evidenced by the beds of trap intercalated in the Lower Carboniferous;* while about the close of the Devonian period still more important injections and intrusions of igneous matter had occurred, as shown by the granitic dykes and masses which traverse the Devonian beds, but have not penetrated the Carboniferous.† There is evidence, however, in the

* Dawson, Quart. Journ. Geol. Soc., vol. i. p. 329.
† Dawson, Canadian Naturalist, 1860, p. 142.

Carboniferous rocks of the Magdalen Islands and of Newfoundland, and in the fringes of such rocks on parts of the coast of Nova Scotia * and New England, that the area in question was only a part of a far more extensive region of Carboniferous deposition, the greater part of which is still under the waters of the Atlantic and of the Gulf of St Lawrence.

There is ample proof that most of the coarser matter of the Carboniferous rocks was derived from the neighbouring metamorphic ridges; but much of the finer material was probably drifted from more distant sources. There seems no good reason to doubt that in the Carboniferous period, and especially in those portions of it in which the areas now under consideration were in the condition of shallow seas or swampy flats, the greater part of the Laurentian and Silurian districts of North America existed as land; while the great number of coal formation plants common to Europe and America may indicate the existence of intermediate lands now submerged. From such lands, undergoing waste during the long Carboniferous period, the materials of the shales and finer sandstones may have been derived.

Taking this view of the source of the sediment, we should infer that the time of the formation of the marine limestones was that of greatest depression of the land, when the local ridges of older rock were mere reefs and islets, and when sediment from more distant lands was deposited only at intervals. We should also infer that the time of the formation of the coal-beds was that of greatest elevation, when the former sea-bottoms had become land-surfaces or flats, exposed only to occasional inundation, and when rivers were bearing downward from large continental regions great quantities of fine silt. Farther, the conditions of the millstone-grit and of the newer coal formation must have been of an intermediate character, requiring wide sea areas receiving great quantities of sediment; and on this account, as well as because of their shallowness, unfavourable to marine life, while the areas of vegetable growth were also of limited extent.

It would also follow that when the lower coal measures and conglomerates were formed, the land was slowly subsiding; that in the time of the marine limestones it attained to its greatest depression, and long remained nearly stationary; that in the Millstone-grit period there was re-elevation, and that in the period of the middle coal formation and Newer Coal formation there was again subsidence, slow and interrupted at first, but subsequently of greater amount. From the absence of Permian deposits, it may be inferred that elevation again took place at the close of the Carboniferous period, to such an

* Jukes's "Newfoundland:" *infra*, chap. xiii.

extent as to preclude further deposition in the area in question; while the red sandstone and trap of Mesozoic age indicate the recurrence at that time of conditions somewhat similar to those of the beginning of the Carboniferous period.

The general phenomena of deposition above indicated, apply to all the Carboniferous areas of Nova Scotia and New Brunswick, and, so far as known, to those of the Magdalen Islands and of Newfoundland. But, as I shall point out in the sequel, numerous local diversities occur, in consequence of the interference of the older elevated ridges with the regularity of deposition. In some places the entire Lower Carboniferous series seems to be represented by conglomerates and coarse sandstones. In others, the Lower Coal measures, or the marine limestones, or both, are extensively developed. These local differences are, on a small scale, of the same character with those which occur on a large scale in the northern and southern Appalachian districts and western districts of the United States, and in the different coal areas of Great Britain and Ireland, as compared with each other and with the Carboniferous districts of America. On the whole, however, it is apparent that certain grand features of similarity can be traced in the distribution of the Carboniferous rocks throughout the northern hemisphere.

It is further to be observed, that in Nova Scotia and New Brunswick, as well as in Eastern Canada, disturbances occurred at the close of the Devonian period which have caused the Carboniferous rocks to lie unconformably on those of the former; and that in like manner the Carboniferous period was followed by similar disturbances, which have thrown the Carboniferous beds into synclinal and anticlinal bends, often very abrupt, before the deposition of the Triassic Red Sandstones. These disturbances were of a different character from the oscillations of level which occurred within the Carboniferous period. They were accompanied by volcanic action, and were most intense along certain lines, and especially near the junction of the Carboniferous with the older formations.

I have noticed an apparent case of unconformability between members of the Carboniferous system near Antigonish.* In the county of Pictou, the arrangement of the beds suggests a possible unconformability of the Upper Coal formation and the Coal measures.† In New Brunswick, Prof. Bailey ‡ has observed indications of local unconformability of the Coal formation with the Lower Carboniferous..

* Quart. Journ. Geol. Soc., vol. i. p. 32.

† *Ibid.*, vol. x. p. 42.

‡ "Report on Geology of Southern New Brunswick," p. 118.

But the strict conformability of all the members of the Carboniferous series in the great majority of cases, shows that these instances of unconformability are exceptional. In the section at the Joggins more especially, the whole series presents a regular dip, diminishing gradually from the margin to the middle line of the trough, where the beds become horizontal.

The most gradual and uniform oscillations of level must, however, be accompanied with irregularities of deposition and local denudation; and phenomena of this kind are abundantly manifest in the Carboniferous strata of Nova Scotia. I have described a bed in the Pictou Coal-field which seems to be an ancient shingle-beach, extending across a bay or indentation in the coast-line of the Carboniferous period.* At the Joggins, many instances occur of the sudden running out and cutting off of beds,† and Mr Brown has figured a number of instances of this kind in the Coal formation of Sydney.‡ They are of such a character as to indicate the cutting action of tidal or fluviatile currents on the muddy or sandy bottom of shallow water. In some instances the layers of sand and drift-plants filling such cuts suggest the idea of tidal channels in an estuary filled with matter carried down by river-inundations. Even the beds of coal are by no means uniform when traced for considerable distances. The beds which have been mined at Pictou and the Joggins show material differences in quality and associations; and small beds may be observed to change in a remarkable manner, in their thickness and in the materials associated with them, in tracing them a few hundreds of feet from the top of the cliff to low-water mark on the beach. I have no doubt that, could we trace them over sufficiently large areas, they would all be found to give place to sandstones, or to run out into bituminous shales and limestones, according to the undulations of the surfaces on which they were deposited, just as the peaty matter in modern swamps thins out toward banks of sand, or passes into the muck or mud of inundated flats or ponds.

Geological Cycles.

The foregoing considerations bring, in a very distinct manner, before us two different, and at first sight irreconcileable, general views which we may take of any given geological period. *First*, we must regard every such period as presenting during its whole continuance the diversified conditions of land and water with their appropriate inhabitants; and *secondly*, we must consider each such period as forming a

* Quart. Journ. Geol. Soc., vol. x. p. 45.

† *Ibid.*, vol. x. p. 12. ‡ *Ibid.*, vol. vi. p. 125 *et seq.*

geological cycle, in which such conditions to a certain extent were successive. As we give prominence to one or the other of these views, our conclusions as to the character of geological chronology must vary in their character; and in order to arrive at a true picture of any given time, it is necessary to have both before us in their due proportion.

We know that the marine animals of the Lower Carboniferous seas continued to exist in the time of the Coal formation, and that some of them survived until the Permian period, proving to us the existence of deep seas even in that age which we regard as specially characterized by swampy flats supporting land-plants. In like manner we know that some of the species of land-plants found in the lowest coal measures continued to exist in the time of the upper coal formation, proving that there was some land suitable for them throughout the epoch of the deep-sea limestones. Regarded from this point of view, any exceptional beds with land-plants in the marine parts of the formation, or beds with sea-shells in the parts where land conditions predominate, acquire a special interest; and so likewise do regions in which, as in some parts of the Appalachian Coal-field, the marine limestones are absent, and those in which, as in some parts of the Western States, marine conditions seem to have continued throughout the whole period. In Nova Scotia, so far as my present knowledge extends, the marine limestones of the Lower Carboniferous cut off the flora of the Lower Coal measures, apparently by a long interval of time, from that of the Middle Coal formation; and in like manner the fossils of the marine limestones cease at the time of the Millstone-grit, and only in one instance, that of a small bed of limestone near Wallace Harbour, partially reappear in the Upper Coal formation.* I have, however, ascertained that the marine limestones may be divided into an upper and a lower member, and that there is some reason to suppose that in some parts of Nova Scotia where the true coal measures are not developed, the upper member may, in part at least, represent them.† On the other hand, I have not as yet been able to bridge over the gulf which separates the flora of the Lower Carboniferous coal measures from that of the Middle Coal formation, an interval which may include much of the "Lower Coal Measures" of Rogers in the Pennsylvania Coal-field.

Turning to that broader view which takes the prevalent conditions of each portion of the period as characteristic, notwithstanding the

* Quart. Journ. Geol. Soc., vol. ii. p. 133.

† Quart. Journ. Geol. Soc., vol. xv. pp. 63 *et seq.* My friend Mr C. F. Hartt, who has more recently studied the marine limestones, has obtained facts which seem to indicate the possibility of a more minute subdivision than any hitherto attempted of these beds. *Vide* chapter on L. C. Limestones, *infra.*

local existence of dissimilar conditions, we not only find, as already stated, that the sequence in Nova Scotia coincides generally with that in other parts of America and in Europe, but that, viewed in this aspect, the Carboniferous period constitutes one of four great physical cycles, which make up the Palæozoic age in Eastern America, and each of which was characterized by a great subsidence and partial re-elevation, succeeded by a second and very gradual subsidence. Viewed in this way, the Lower Carboniferous conglomerate and Lower Coal measures correspond analogically with the Oriskany sandstone, the Oneida and Medina sandstones, and the Potsdam and Calciferous sandstones. The Carboniferous limestone corresponds with the Corniferous limestone, the Niagara limestone, and the Trenton group of limestones. The coal measures correspond with the Hamilton group, the Salina group, and the Utica shale. The Upper Coal formation corresponds with the Chemung, the Lower Helderberg, and the Hudson-River groups. The Permian is not represented in Eastern America; but, as developed in Europe, it clearly constitutes a similar cycle. These parallelisms, which deserve more attention from geologists than they have yet received, may be tabulated thus:—*

Tabular View of Cycles in the Palæozoic Age in Eastern America.

(The several formations are arranged in descending order.)

Character of Group.	Lower Silurian.	Upper Silurian.	Devonian.	Carboniferous.
Shallow, subsiding marine area, filling up with sediment............	Hudson-River group.	Lower Helderberg group.	Chemung gr.	Upper coal formation.
Elevation, followed by slow subsidence, land-surfaces, etc............	Utica shale.	Salina group.	Hamilton gr.	Coal measures.
Marine conditions; formation of limestones, etc.......	Trenton, Black R. and Chazy limestones.	Niagara and Clinton limestones.	Corniferous limestone.	Lower Carboniferous limestone.
Subsidence; disturbances; deposition of coarse sediment............	Potsdam and Calciferous sandstones.	Oneida and Medina sandstones.	Oriskany sandstone.	Lower Coal measures and conglomerate.

In the Permian of Europe, the Stinkstein, the Rauchwacke, the Zechstein, and the Rothliegendes might form a fifth parallel column. Of course such parallelism might be variously expressed, by reckoning a smaller or larger number of groups. Independently of these different modes of statement, however, I believe that the basis of such comparisons exists in nature, and that it will prove possible to sub-

* Dr Sterry Hunt has directed attention to them in a paper "On Bitumens," Silliman's Journal [2], xxxv. p. 166, and in the "Geology of Canada," 1863, p. 627; and Dana refers to them in his "Manual of Geology." Eaton and Hall had previously noticed these parallelisms.

divide geological time into determinate natural cycles, the parts of which are analogous to those of similar cycles. A further question to be solved is, whether such cycles corresponded in all parts of the world, or whether, as is more likely, the earth might be divided into areas in which in each cycle elevation and subsidence were contemporaneous. So far as the present subject is concerned, I merely desire to show that the Carboniferous rocks of Nova Scotia represent a complete cycle of the earth's history, and correspond in time with the Carboniferous of Europe, and in value with the other great divisions of the Palæozoic age.

Summary of facts relating to the mode of accumulation of Coal.

With regard to this important subject, I would rather invite attention to the details to be presented in subsequent pages, than make any preliminary general statements. It is, however, necessary to notice here the several views which have prevailed as to the probable accumulation of coal by driftage or growth *in situ*, in water or on land. I have already, in previous publications,* stated very fully the conclusions at which I have arrived on some portions of this subject, and I would now sum up the more important general truths as follows:—(1.) The occurrence of *Stigmaria* under nearly every bed of coal, proves beyond question that the material was accumulated by growth *in situ;* while the character of the sediments intervening between the beds of coal proves with equal certainty the abundant transport of mud and sand by water. In other words, conditions similar to those of the swampy deltas of great rivers are implied. (2.) The true coal consists principally of the flattened bark of Sigillarioid and other trees, intermixed with leaves of ferns and *Cordaites*, and other herbaceous debris, and with fragments of decayed wood constituting "mineral charcoal," all these materials having manifestly alike grown and accumulated where we find them. (3.) The microscopical structure and chemical composition of the beds of cannel-coal and earthy bitumen, and of the more highly bituminous and carbonaceous shales, show them to have been of the nature of the fine vegetable mud which accumulates in the ponds and shallow lakes of modern swamps. When such fine vegetable sediment is mixed, as is often the case, with clay, it becomes similar to the bituminous limestone and calcareo-bituminous shales of the coal measures. (4.) A few of the underclays which support beds of coal are of the nature of the vegetable mud above referred to; but the greater part are argillo-

* "On the Structures of Coal," Quart. Journ. Geol. Soc., vol. xv., also vol. xxii., p. 95, etc. "Air-breathers of the Coal Period," Montreal, 1863, p. 18.

arenaceous in composition, with little vegetable matter, and bleached by the drainage from them of water containing the products of vegetable decay. They are, in short, loamy or clay soils, and must have been sufficiently above water to admit of drainage. The absence of sulphurets, and the occurrence of carbonate of iron in connexion with them, prove that, when they existed as soils, rain-water, and not sea-water, percolated them. (5.) The coal and the fossil forests present many evidences of subaërial conditions. Most of the erect and prostrate trees had become hollow shells of bark before they were finally imbedded, and their wood had broken into cubical pieces of mineral charcoal. Land-snails and galley-worms (*Xylobius*) crept into them, and they became dens or traps for reptiles. Large quantities of mineral charcoal occur on the surfaces of all the larger beds of coal. None of these appearances could have been produced by subaqueous action. (6.) Though the roots of *Sigillaria* bear some resemblance to the rhizomes of certain aquatic plants, yet structurally they are absolutely identical with the roots of Cycads, which the stems also resemble. Further, the *Sigillariæ* grew on the same soils which supported Conifers, *Lepidodendra*, *Cordaites*, and ferns—plants which could not have grown in water. Again, with the exception, perhaps, of some *Pinnulariæ* and *Asterophyllites*, there is a remarkable absence from the coal measures of any form of properly aquatic vegetation. (7.) The occurrence of marine or brackish-water animals in the roofs of coal-beds, or even in the coal itself, affords no evidence of subaqueous accumulation, since the same thing occurs in the case of modern submarine forests. For these and other reasons, some of which are more fully stated in the papers already referred to, while I admit that the areas of coal accumulation were frequently submerged, I must maintain that the true coal is a subaërial accumulation by vegetable growth on soils wet and swampy, it is true, but not submerged. I would add the further consideration, already urged elsewhere, that, in the case of the fossil forests associated with the coal, the conditions of submergence and silting-up which have preserved the trees as fossils, must have been precisely those which were fatal to their existence as living plants—a fact sufficiently evident to us in the case of modern submarine forests, but often overlooked by the framers of theories of the accumulation of coal.

It seems strange that the occasional inequalities of the floors of the coal-beds, the sand or gravel ridges which traverse them, the channels cut through the coal, the occurrence of patches of sand, and the insertion of wedges of such material splitting the beds, have been regarded by some able geologists as evidences of the aquatic origin

of coal. In truth, these appearances are of constant occurrence in modern swamps and marshes, more especially near their margins, or where they are exposed to the effects of ocean-storms or river-inundations. The lamination of the coal has also been adduced as a proof of aqueous deposition; but the microscope shows, as I have elsewhere pointed out, that this is entirely different from ordinary aqueous lamination, and depends on the superposition of successive generations of more or less decayed trunks of trees and beds of leaves. The lamination in the truly aqueous cannels and carbonaceous shales is of a very different character.

It is scarcely necessary to remark, that in the above summary I have had reference principally to the appearances presented by the coal formation of Nova Scotia; though I believe that in a general way the conclusions stated will hold good in other countries, as has indeed been shown by the admirable researches on this subject of Brongniart, Goeppert, Newberry, Binney, Rogers, Lesquereux, and others, whose publications on this subject I have read with interest, and have tested in their application to the phenomena presented to me in the coal-fields of Nova Scotia. I may add, that, in my opinion, the phenomena of the Stigmaria underclays, to which attention was first directed by Sir W. E. Logan, furnish the key to the whole question of the origin of coal, and that the comparisons of coal-deposits, by Sir Charles Lyell, with the "cypress-swamps" of the Mississippi, perfectly explain all the more important appearances in the coal formation of Nova Scotia.

In the above pages I have endeavoured to state some general results of the study of the Carboniferous rocks which may be useful as introductory to their more detailed investigation. I now proceed to consider the local distribution of these rocks in Acadia, and their subdivision into areas more or less distinct.

The reader must understand that the actual superposition and arrangement of all this great thickness of beds, are ascertained by the examination of coast and river sections, in which portions of the series are seen tilted up, so that they can, by proceeding in the direction toward or from which they incline, be seen to rest on each other. There is one coast section in Nova Scotia so perfect that nearly the whole series is exposed in it. On the other hand, there are large areas in which the lower portion alone exists, and perhaps never was covered by the upper portions; and there are other areas in which the upper members have covered up the lower, so that they appear only in a few comparatively limited spots.

The area occupied by Carboniferous rocks in Nova Scotia and New

Brunswick is very extensive; and it is divided by ridges of the older metamorphic rocks into portions which may for convenience be considered separately. These are—

1. The New Brunswick Carboniferous district, the largest in point of area in the Acadian provinces.

2. The Cumberland Carboniferous district, bounded on the south by the Cobequid Hills, and continuous on the north-west with the great Carboniferous area of New Brunswick.

3. The Carboniferous district of Minas Basin and Cobequid Bay, and its outliers, including the long band of Carboniferous rocks extending along the south side of the Cobequids, and that reaching along the valley of the Musquodoboit River.

4. The Carboniferous district of Pictou, bounded on the south and east by metamorphic hills, and connected on the west with the Cumberland district and that last mentioned.

5. The Carboniferous district of Antigonish county, bounded by two spurs of the metamorphic hills.

6. The narrow band of Carboniferous rocks extending from the Strait of Canseau westward through the county of Guysboro'.

7. The Carboniferous district of Richmond county and southern Inverness.

8. The Carboniferous district of Inverness and Victoria counties.

9. The Carboniferous district of Cape Breton county.

New Views promulgated by Professor Lesley. Comparison with the Carboniferous of Europe.

It may be proper here to refer to points raised by J. P. Lesley, Esq. of Philadelphia, in a Report on the Glace Bay Coal-field,* which appear at variance with the view above given of the constitution of the Carboniferous system in Nova Scotia. As Mr Lesley deservedly ranks high as an authority in the Coal formation, and as his views on this subject, though originating, in my opinion, in misconception and imperfect opportunities for observation, were widely circulated in the United States, and were introduced into an official Report in Nova Scotia, it would be wrong to pass them by without notice. Professor Lesley says:—"Sir William Logan, Sir Charles Lyell, Professor Dawson, and other geologists, who have described the Coal measures of Nova Scotia and New Brunswick, agree in assigning to them an almost incredible thickness." He then proceeds to compare, on lithological grounds, the shales of Division 5 of Logan's section at the Joggins, with the Lower Carboniferous or Vespertine (No. XI.)

* Proceedings of American Philosophical Society, Philadelphia, 1862.

of Pennsylvania; and consequently would place the Millstone-grit and the Lower Carboniferous limestones and Lower Coal measures on the parallel of the Devonian rocks. Such a sweeping change, merely on the ground of similarity of mineral character, and in opposition to the evidence of fossils, and to the fact of the true Upper Devonian occurring in its proper place in New Brunswick, would, unless advocated by a geologist of the standing of Professor Lesley, scarcely deserve notice. In the circumstances, however, I considered it my duty to send to the Society in whose proceedings Professor Lesley's paper appeared, and of which I have the honour to be a Fellow, the following statement of objections to Professor Lesley's views, which I give in full, with Professor Lesley's rejoinder and my further explanations, because the points involved are of much importance and incidentally bring out several very interesting considerations in regard to the Coal formation. Their importance in a practical point of view may be judged from the fact to be noticed in the sequel, that Professor Lesley's conclusions induced him to diminish by one half the thickness of the Coal formation of Cape Breton, as ascertained by Mr Brown, and thus to ignore altogether the extension to the eastward of the Sydney coal-beds in rear of those of Glace Bay. I have to thank Professor Lesley for the courtesy with which, as Secretary to the Philosophical Society, he attended to my communications, and the fairness with which he met my objections; and although I know that he must be (I hope I may say, have been) in error in this point, it is scarcely necessary to say that there is no one for whose geological acumen I entertain more respect.

Note on Mr Lesley's Paper on the Coal Measures of Cape Breton.

The new facts and general considerations on the Nova Scotia coal-field contained in this paper are of the highest interest to all who have worked at the geology of Nova Scotia. I think it my duty, however, to take exception to some of the statements, which, I think, a larger collection of facts would have induced Mr. Lesley himself to modify. My objections may be stated under the following heads:—

(1.) It is scarcely safe to institute minute comparisons between the enormously developed coal measures of Nova Scotia and the thinner contemporary deposits of the West, any more than it would be to compare the great marine limestones of the period at the West with the slender representatives of that part of the group to the eastward.

(2.) There is the best evidence that the coal measures of Nova Scotia never mantled over the Devonian and Silurian hills of the Province, but were, on the contrary, deposited in more or less separate areas at their sides.

(3.) Any one who has carefully compared the coal measures of the Joggins with those of Wallace and Pictou, must be convinced of the hopelessness of comparing individual beds, even at this comparatively small distance. *A fortiori* detailed comparisons with Pennsylvania and more distant localities must fail.

(4.) I do not think that any previous observer has supposed that the coal measures of Eastern Cape Breton represent the whole of the coal formation of Nova Scotia. The "Upper Coal measures" of my papers on Nova Scotia are certainly wanting, and probably the Sydney Coal-field exhibits no beds higher than No. 4 of Logan's Joggins section.

(5.) The whole of the coal-beds in the Joggins section belong to the *Upper* and *Middle* coal measures. It is quite incorrect to identify No. 6 of Logan's section with the *Lower* Coal measures. These do not occur at the Joggins, but are found in Nova Scotia, as in Virginia and Southern Pennsylvania, at the base of the system, under the marine limestones. The Albert beds are the equivalents of these lower measures, and not of the Pictou coal. In my paper on the Lower Carboniferous coal measures (Journal of Geological Society of London, 1858), will be found a summary of the structure of the Lower Coal measures, as shown at Horton Bluff, and elsewhere. The term "true coal measures," quoted by Mr. Lesley, does not mean in my description the Middle Coal measures, but merely that part of them holding the workable coal-seams.

(6.) Whatever may be the value of M. Lesquereux's applications of the fossil flora to the identification of coal-seams in the West, I am prepared to state, as the result of an extensive series of observations, still for the most part unpublished, that in Nova Scotia the flora is identical throughout the whole enormous thickness of the Middle coal measures, and that the differences observable between different seams are attributable rather to difference of station and conditions of preservation than to lapse of time. It is indeed true, as I have elsewhere explained, that the assemblages of species in the Lower, Middle, and Upper Coal measures may be distinguished; but within these groups the differences are purely local, and afford no means for the identification of beds in distant places.

(7.) I do not desire to offer any opinion on the questions raised by some American geologists as to the extension of the term Carboniferous to the Chemung group; but I know as certain facts, that the flora of the Lower Coal measures, under the marine limestones and gypsums of Nova Scotia, is wholly Carboniferous, and that the *flora*, on which alone I consider myself competent to decide, of the Chemung of New

York, as now understood by Professor Hall and others, and also of the groups in Pennsylvania, named by Rogers Vergent and Ponent (? IX. and X. of Mr Lesley), is as decidedly Devonian, and quite distinct from that of the Carboniferous period.*

For Mr Lesley's ability as a stratigraphical geologist I have the highest respect; and with reference to the present subject, would merely desire to point out that he may not have possessed a sufficient number of facts to warrant some of his generalizations, on which in the meantime I would, for the reasons above stated, desire geologists to suspend their judgment.

The following is the rejoinder of Professor Lesley, omitting some general discussions not important to the subject in hand:—

"Professor Dawson's first objection is a begging of the very question, Whether the coal measures of Nova Scotia *are* 'enormously developed?' That, in one little spot of the earth's surface like Nova Scotia, and that, too, midway between the great coal areas of America and those of Europe, wherein the thickness of coal measures proper ranges from 2000 to 5000 feet, if they even attain the latter size, there should be an anomalous deposit of 25,000 feet, is incredible. What the great Bohemian palæontologist, by unerring instinct, said to us after our thirty years' war over the Taconic system, *there must be a mistake somewhere*, I must repeat to those who so 'enormously develop' the Nova Scotia coal measures. And my intention in the paper on Nova Scotia coal was only to suggest one formula on which the error might be discussed. I distinctly repudiated the safety of instituting 'minute comparisons.' My comparison of the Cape Breton coals and the column at Pittsburg was carefully made in the most general manner, and the resemblance called a coincidence. But the value of the comparison remains; for it affords a new argument in favour of the *family likeness* of those parts of the general coal measures of different countries, which have a right to the specific title of 'productive coals.' The argument also remains good, that if 2000 feet of coal measures in Missouri can be recognised in 2000 feet of coal measures in Kentucky, Virginia, and Eastern Pennsylvania, the very same system of beds, bed for bed, being demonstrated first by stratigraphy, and then by palæontology (and such is the fact), why not in Nova Scotia?

"I have no doubt that some of the coal measures of the British Provinces may have been 'deposited in more or less separated areas at the sides of the Devonian and Silurian hills,' as Professor Dawson

* See Paper on Devonian Flora of Eastern America, Jour. Lond. Geol. Soc. November, 1862.

says (2). But I confess to a complete scepticism of the great extent which has been assigned to this unconformability of the coal measures upon the lower rocks; first, because most of the Island of Cape Breton, and much of the surface of Nova Scotia and New Brunswick, are confessedly unstudied and almost unknown; secondly, because the incredible thickness assigned to the coal measures throws doubt upon the positions assigned to the unconformable horizons; thirdly, because the coal-beds themselves stand almost vertical in many places round the shores; fourthly, because the mountains of Nova Scotia, with apparently conformable Carboniferous limestones, have apparently an Appalachian structure and aspect, have suffered vast denudation, exhibit cliff outcrops and section ravines, and may just as well have carried coal upon their original backs as we can prove that our Tussey, Black Log, Nescopec, Mahoning, Buffalo, Tuscarora, Brush, and other Silurian and Devonian mountains did. There is an immense unconformable chasm in the column west of the Hudson River, and the Catskill Mountains over it have no coal upon their backs; but the coal comes in regularly enough on them at the Lehigh (a less distance than from Sydney to St Peters, or from Pictou to Windsor), and the unconformability in the Upper Silurian and Devonian has already disappeared.

"Professor Dawson's fourth objection would be good, if I had really 'supposed the coal measures of eastern Cape Breton to represent the whole of the coal measures of Nova Scotia.' But I only suggested that they may prove to be the equivalents of the system of *productive coal measures*; that is all. Between the Monongahela and the Ohio, our column of productive coals is capped by another of barren shales and soft sandstones of unknown height, by one estimate 3000 feet thick; and part of this column may represent the so-called Permian measures, which, in Kansas, cap conformably the coal measures. Having no knowledge of the fossils, I have no desire to oppose the conclusions of Professor Dawson, as to the part of the column of the Joggins in which the Glace Bay coals apply, but hope that his accurate handling of them will secure some certainty about it. It was the grouping of the beds, and not the fossils, which I wished to bring into prominent notice; because the doctrine of isolated basins, when unfounded or overapplied, is as injurious to lithological truth as the careless identification of surface aspect may at any moment prove to palæontology. I willingly leave to accomplished palæontologists like Professor Dawson, the discussion of the grand generalization embodied in his sixth objection; but I may be permitted to believe that it has had its birth in the doctrine of isolated basins, and

that the two must stand or fall together. It also seems to me to involve radical inconsistencies; for if I comprehend it, it asserts (1.) That the flora of the whole coal measures (25,000 feet?) is identical; that is, the vertical distribution of each and all the plants is complete from the bottom to the top. (2.) That nevertheless there are differences observable between different coal-beds. (3.) That these are attributable rather to difference of station and conditions of preservation than to lapse of time; that is, if we could take the beds, each one in its whole extent and its fossils in their original condition, there would be no differences observable between different seams after all. (4.) That groups or assemblages of species in the Lower, Middle, and Upper Coal measures may nevertheless be distinguished; that is, while each and every species may be found occasionally in all parts of the column from bottom to top, yet this happens in such a manner as to group some of them more abundantly, or in certain peculiar proportions in the Lower, others in the Middle, and others in the Upper portions of it. (5.) That, after all, however, these groups are not persistent, but differ at different localities, and are as worthless as the specific forms themselves for the identification of a single bed in more than one place.—Is it possible that all this has been made out, or *can* be made out, except in a country of *horizontal* coal measures, well opened for study, where the stratification can be established beforehand, and the range of the fossils be undoubted?"

With reference to this rejoinder, as Professor Lesley seemed to have misapprehended some of the points briefly stated in my first letter, I thought it necessary to make the following additional explanations:—

"1. Dr Dawson is not aware that he has, at any time, maintained that the "coal measures proper" of Nova Scotia are 25,000 feet in thickness. In speaking of their enormous thickness, he referred to the actual measurements of Sir W. E. Logan at the Joggins, which give for the whole of the Carboniferous rocks seen in that section, a vertical thickness of 15,570 feet, and for the coal measures proper, or Middle Coal formation, a thickness of rather less than 10,000 feet. The objections based by Mr Lesley on this supposed thickness of 25,000 feet, are therefore quite inapplicable to the views of Dr Dawson.

"2. Dr Dawson does not admit the interpretation of his views as to the unity of the coal flora given by Mr Lesley. The 'inconsistencies' alleged by the latter depend in part on the imaginary thickness of 25,000 feet attributed to the Middle Coal measures. The identity of the flora throughout the Middle Coal formation, and the distinctions between this and the assemblages of plants in the Lower and Upper

Coal formation, admit of being readily ascertained, where good exposures exist, as in Nova Scotia; and it is to be borne in mind that my investigations on this subject have extended over more than twenty years, though many of the details ascertained have not yet been published.*

"3. It should be understood that the Carboniferous system in Nova Scotia consists of the following members:—

"(1.) *The Upper Coal Formation.*

"(2.) *The Middle Coal Formation.*

"(3.) *The Millstone-grit Series*, represented in Nova Scotia by red and gray sandstone, shale, and conglomerate, with a few fossil plants and thin coal seams, not productive.

"(4.) *The Carboniferous Limestone*, with the associated sandstones, marls, gypsum, etc., and holding marine fossils, recognised by all palæontologists who have examined them as Carboniferous.

"(5.) *The Lower Coal Measures*, holding some but not all of the fossils of the Middle Coal formation, and thin coals, not productive; but differing both in flora and fauna from the Upper Devonian, which, in New Brunswick, they overlie unconformably.

"The principal, though not the only point in which Mr Lesley differs from Logan, Lyell, Brown, and Dawson, is his entire omission of No. 5 of the above series, and placing No. 3 in its room, as the representative of the Lower Coal measures of Virginia and Pennsylvania. I have, I think, already made this sufficiently plain in the fifth of my objections, already published; but may add here that fossils as well as stratigraphical position establish the real equivalency of No. 5, and not No. 3, to the Lower Coal formation, as described by Lesquereux in America, and by Goeppert in Europe; and that it seems strange that Mr Lesley, while suggesting minor and more dubious parallelisms, declines to admit this identification, established by long and careful investigations of several competent observers, and confirmed by the evidence of fossils."

It will be seen from the above discussion, that the Carboniferous series in Nova Scotia, though limited in area, is of great thickness; and that within the limits of Acadia the strictly marine as well as the coal-bearing portions of this great group of rocks are represented with a completeness not to be found in any one coal area of the United States, where the marine limestones are enormously developed in the west at the expense of the coal measures, and the latter at the expense of the marine members in the east.

In the United States, however, the Lower Coal measure flora has

* Since published—Journal of Geol. Society, May 1866.

been recognised by Lesquereux, who has also marked out a number of interesting parallelisms in the beds of the Middle Coal formation. In Illinois and Iowa, the Lower Carboniferous marine limestones present several important subdivisions, and still farther west there appear to be Upper Carboniferous marine beds graduating upward into Permian.

In England the Mountain Limestone, the Millstone-grit, and the Coal Formation, have been the members usually recognised, but recently attention has been attracted to the Lower Coal measures, which are also developed there; and in 1865, I saw in the Museum of the Geological Survey a small collection of undetermined plants from these beds, perfectly corresponding to those of the Lower Coal formation of Nova Scotia. The term Lower Coal measures is, however, in England and Scotland, usually applied to beds corresponding to the lower part of the Middle Coal formation of the above classification. With regard to the Upper Coal formation, its equivalent is recognised in the English and Scottish coal-fields as the overlying barren coal measures, either destitute of coal or with thin and unworkable seams, and which in the Lancashire Coal-field amount to nearly 2000 feet in thickness. In Lancashire these beds are very similar to the corresponding series in Nova Scotia. In the Scottish coal-fields they contain marine limestones,—a circumstance which occurs in one instance in Nova Scotia. Much remains to be done in Great Britain for the proper working out of the distinction in the flora of the members of the Carboniferous system, the study of fossil plants of the coal having been much neglected by geologists.

In Germany, where the subject of the coal flora has received greater attention, the subdivisions have been more fully worked out; and I have much pleasure in quoting the following remarks by Professor Geinitz of Dresden, from a review of my paper on the "Conditions of Accumulation of Coal," in the "Isis," 1866:—

"In comparing the distribution of this flora with that in the various zones of the Carboniferous of Europe, it is first of all a surprising fact, that there also the zone of the Lower Coal formation must be designated, as in Europe, the Lycopodiaceous zone, since *Lepidodendron corrugatum* is the most remarkable and predominant plant in it. But this species approaches so closely the *Lycopodites polyphyllus*, Rom. sp. (Geinitz, Flora of the Hainichen, Ebersdorf Basin), that both of them might be considered as identical, whilst *Lep. tetragonum* St. (Gein., etc.), and *Knorria imbricata* St. (Gein., etc.), which we must still continue to regard as an independent plant, are likewise quite characteristic of the oldest Coal formation or culm of Europe. The

Cyclopteris Acadica, Daws., of the Lower Coal measures of North America, also is very nearly allied to the *Cyclopteris tenuifolia*, Göpp., in the German culm.

"The predominance of the *Sigillaria* and *Stigmaria* in the Middle Coal formation, proves the identity of this zone with our European zone of *Sigillaria;* and the analogy with the flora of the principal beds of coal of England and Ireland is particulary striking, especially through the great extension of the *Alethopteris lonchitica*, which is never wanting there.

"When, finally, Dawson sets forth in a prominent manner, that in the uppermost division of Sir W. Logan's section of the South Joggins, which corresponds with the upper part of the Upper Coal formation, trunks of conifers and Calamites, *Cal. Suckovii*, etc., and *C. approximatus*, by the side of *Aspidiaria*, etc., are the fossils most frequently to be met with, we are enabled to place this zone nearly on a level with the zone of *Calamites*, or the third band of vegetation in Germany.

"Thus the succession in the flora of the Coal formation, as we have ascertained it for Europe, appears to have been established for America also by Dr Dawson's profound investigations, and they will probably soon be followed by the discovery of the existence of the two upper zones,—the '*Annularia*' and 'Fern' zones."

It will be observed that Professor Geinitz anticipates the separation of two additional zones in the Upper Coal formation. Of these I have as yet no distinct evidence, and the paucity of fossils in these Upper rocks may render it difficult to make such distinctions. Undoubtedly, however, *Annularia galioides*, *Cordaites simplex*, and several ferns, as *Pecopteris arborescens* and *Alethopteris nervosa*, are characteristic of some of the newest beds known to me in the coal-field of Pictou.

CHAPTER XI.

THE CARBONIFEROUS SYSTEM—*Continued.*

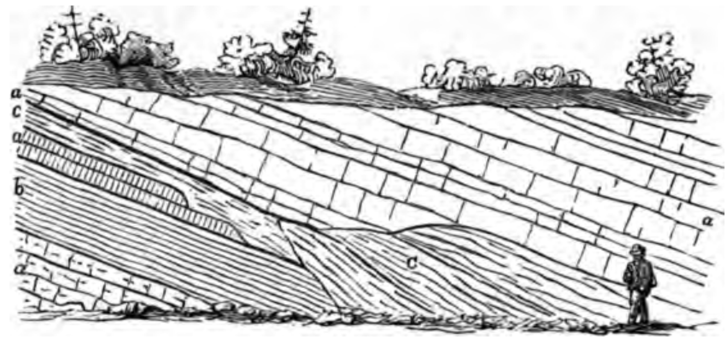
CARBONIFEROUS DISTRICT OF CUMBERLAND — SECTION AT THE SOUTH JOGGINS.

Though the great triangular area of Carboniferous rocks in eastern New Brunswick is the largest in Acadia, it does not present such admirable facilities for the study of these rocks as those afforded by the coast sections in Western Cumberland; we shall therefore first study these with some minuteness, as typical of the whole Acadian Carboniferous districts, and afterwards notice the larger New Brunswick area.

The rocks of the Cumberland Carboniferous area have a general trough-shaped arrangement, which in the western part of the county at least appears to be very regular. (See General Section.) On the south side, all along the base of the Cobequids, we find conglomerates and other Lower Carboniferous rocks dipping to the north, and forming the southern edge of the trough. Resting on these are the beds of the Coal formation, still dipping to the northward. Toward the centre of the county, we find the rocks of the Upper Coal formation slightly inclined and finally dipping to the south, to form part of the northern side of the trough. Proceeding onward, we find the repetition of the Older Coal formation and Lower Carboniferous series with southerly dips. The latter extends into New Brunswick, where it turns over and dips to the northward, underlying the great Carboniferous plain of that province. In crossing the county of Cumberland, this regular arrangement of the beds is evidenced by the long parallel ridges that cross the country from east to west, and which are produced by the outcropping edges of beds of firm sandstone, which have resisted wasting agencies better than the softer beds that occur between them. There is, however, reason to believe, as we shall find in the sequel, that in the central and éastern part of the Cumberland trough there are subordinate undulations which prevent the coal-beds from running continuously across the country, and that in some places the Coal forma-

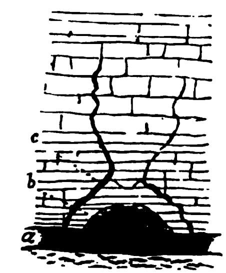
SECTIONS, ETC.—SOUTH JOGGINS COAL FORMATION.

Erect Calamites crushed by Lateral Pressure.



Denudation and Filling up.

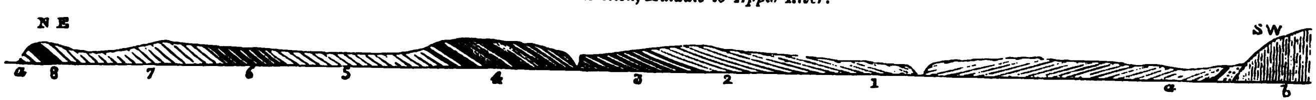
a, Sandstone. *b*, Shale. *c*, Irregularly bedded Sandstone and Remains of Plants.



Section of Remains of an Erect Tree.

a, Coal. *b*, Mineral charcoal. *c*, Coaly remains of bark.

General Section, Minudie to Apple River.



a, Carboniferous. *b*, Silurian. Figs. 1 to 8 indicate the Subdivisions of Logan's Section of the South Joggins.

tion seems to abut against the older rocks of the Cobequid Mountains, without the intervention of the Lower Carboniferous. On the western coast of the county, the cliffs fronting Chiegnecto Bay and Cumberland Basin, and which have been cut and are kept clean and fresh by the same agencies which we have already noticed in treating of the Trap and New Red Sandstone coasts, furnish the best and most complete section of the Carboniferous rocks in Nova Scotia, and one of the finest in the world; and on this account I shall commence with its description, as affording the best guide to the understanding of the more obscure and complicated parts of the formation.

This remarkable section, now well known to geologists as the South Joggins section, extends across almost the whole north side of the Cumberland trough, and exhibits its beds in a continuous series, dipping S. 25° W. at an angle of 19°; so that in proceeding along the coast from north to south, for a distance of about ten miles, we constantly find newer and newer beds; and these may be seen both in a bold cliff and in a clean shore, which at low tide extends to a distance of 200 yards from its base. We thus see a series of beds amounting to more than 14,000 feet in vertical thickness, and extending from the marine limestones of the Lower Carboniferous series to the top of the Coal formation. In the cliff and on the beach, more than *seventy* seams of coal may be seen, with their roof-shales and underclays, and erect plants appear at as many distinct levels; while the action of the waves and of the tide, which rises to the height of forty feet, prevents the collection of debris at the foot of the cliff, and continually exposes new and fresh surfaces of rock.

In describing this section, I shall take as guides Sir W. E. Logan's elaborate section of the whole coast, including 14,570 feet 11 inches of vertical thickness, and a re-examination of 2800 feet of the most interesting part of the section made by Sir Charles Lyell and the writer in 1852 and 1853, and published in the Proceedings of the Geological Society of London for the latter year, with additional facts ascertained by myself in subsequent visits, and many of which have been published in my more recent papers. I shall proceed in the *ascending* order, or from the older to the newer beds, and shall interpret each new appearance as it occurs. In this way I hope to give to the attentive reader a more accurate idea of the structure and mode of formation of a coal-field than he could obtain in any other way, except by an examination of the actual coast section described.

The oldest beds of the Lower Carboniferous series do not appear in the coast section, but may be studied at Napan River and other places near Amherst. They consist of sandstones and marly clays, including

thick beds of limestone and gypsum. The mode of formation of this last rock I shall not now notice, as better opportunities will occur hereafter. Respecting the limestones, I may remark that they are marine deposits, formed in an open sea tenanted by various kinds of shell-fish, etc., the remains of which still exist in the limestone. They are principally bivalves of a family (the *Brachiopoda*) once very abundant, but in the modern world represented by very few species; and the most abundant shell of this kind in these limestones is the *Productus Cora*, a finely striated species, having one valve very convex externally, and the other very concave. It is found in rocks of the same age in Great Britain. There is also a nautilus, nearly resembling in form the nautilus of recent tropical seas, but smaller in size; and there are numerous fragments of *Crinoids*, a tribe of creatures allied to modern star-fishes, but furnished with a stem by which they were attached to the bottom, while their radiating arms extended on all sides in quest of prey. These limestones must have been formed in a sea whose waves lashed the slopes of the Cobequid Mountains and ground up the pebbles of old rocks which now form conglomerates on their flanks, while beds of shells were accumulating in its more quiet depths. Its northern boundary may have been the Silurian and metamorphic rocks of Lower Canada and Labrador.

The limestones above described dip to the southward; and if we proceed across the country in the direction of their strike, we find them again with the same fossils on the Hebert River near Minudie; and in the opposite or eastern direction, at several places nearly in a line between the Napan and Pugwash Harbour on the shore of Northumberland Strait, where the limestone with its characteristic marine fossils is largely developed. Leaving in the meantime the rocks that lie to the northward of and under this limestone, we may take that part of it which appears near Minudie as the base of the Joggins section. Following its direction across from Hebert River to the Joggins coast, we find there that it is overlaid conformably by a great series of sandstones and shales, which we shall now proceed to describe, just as we should see them if walking along the coast; and if this process should seem at all tedious to the reader, I beg him to remember that this finely exposed series of beds furnishes the key which will enable us to understand the whole structure of the Coal formation of Nova Scotia and New Brunswick; and further, that this key to facts so important both in geology and in reference to the economical value of the coal-fields, is now for the first time brought in a complete form before the general reader.

Commencing at Seaman's Brook in Mill Cove, and taking Logan's

carefully detailed section as our guide, we see in the low cliff and in the shore-reefs beds of reddish and gray sandstone, alternating with reddish shales or beds of hardened and laminated clay. In a few places we find among these beds layers of gypsum and of a coarse sandy limestone. In several of the gray beds there are fragments of trunks and branches of trees, converted into coal, and resembling, what they certainly once were, drift trees embedded in sand-banks. Associated with these remains, we find in four of the beds small quantities of the gray sulphuret and green carbonate of copper, minerals introduced into these beds by waters holding sulphate of copper in solution, which the carbonaceous matter of the fossil wood has deoxidized, and thereby caused its deposition. Such appearances are not infrequent in beds containing fossil plants, but they have not hitherto been found to afford sufficient quantities of copper to be of any practical value. I may also remark here, in connexion with the occurrence of fossil plants in gray rather than in red beds, that in the coal formation, as in the modern marshes and peat-bogs already described, the presence of vegetable matter has often destroyed the red colour of beds tinged with peroxide of iron, and hence the fossils are in some sense the cause of the gray colour of the beds in which they are found. Beds of the kinds just described occupy the shore to a distance equal to 2308 feet, as ascertained by the careful measurements of each bed made by Sir W. E. Logan. I may remind the reader, that as these beds dip to the south-west, we are constantly proceeding from older to newer beds.

In the succeeding 3240 feet of beds we find a similar series, with some additional features indicating our approach to the great masses of fossil vegetables entombed in the true coal measures which overlie them. There are here nine seams of coal, all very thin, their total thickness being only ten inches; and under each seam we observe a bed of clay or crumbling argillaceous sandstone, with remains of roots belonging to plants to be noticed hereafter, and which had much to do with the accumulation of the coal. We find also in this thick series of sandstones and shales several bands of hard black limestone, yielding a bituminous and almost animal smell when rubbed or struck, and containing abundance of little diamond-shaped plates with smooth and polished surfaces, which, if we are acquainted with the animals of the Coal period, we recognise as the scales of a singular tribe of fish, the Ganoids, of which numerous species abounded in the Carboniferous period, but which are now represented in America only by the bony pikes of the Canadian lakes, and a few other fresh-water fishes. There is also in this part of the section a far greater prevalence of gray sandstones than in the part previously noticed, and in these gray sandstones

are immense quantities of fossil plants, most of them trunks of trees confusedly intermingled and flattened more or less by pressure; others long cylindrical reed-like stems (*Calamites*), or immense creeping roots dotted all over with pits from which their rootlets sprang (*Stigmariæ*). In most of these fossils the bark is converted into hard shining coal, but the wood has decayed away, and the hollow cavity left within the bark, has been filled with sand now hardened into stone like that without. This is a distinct process from petrifaction properly so called, in which the minute cells of the wood become so filled with mineral matter that the minutest parts of the structure are preserved. Some of the gray sandstones of this part of the section are of great thickness, and in them are the most important quarries of the Joggins grindstones, which are exported to all parts of the United States. These grindstones have been formed from beds of sand deposited in such a manner that the grains are of nearly uniform fineness, and they have been cemented together with just sufficient firmness to give cohesion to the stone, and yet to permit its particles to be gradually rubbed off by the contact of steel. A piece of grindstone may appear to be a very simple matter, but it is very rarely that rocks are so constituted as perfectly to fulfil these conditions, and hence the great demand for the Joggins stone.

This part of the section suggests many interesting inquiries respecting the mode of formation of some of its beds, but I postpone these till we arrive at those portions which show coal measures, properly so called, on a somewhat larger scale.

Proceeding along the coast, we find that the strata last described are overlaid by a series amounting to 2082 feet in vertical thickness, and differing from the last group of beds in containing fewer gray sandstones, no coal-seams or bituminous limestones, and comparatively few fossil plants, and these but imperfectly preserved. This series, then, consists in great part of reddish shales and reddish and gray sandstones. These, and indeed the greater part of the rocks composing the part of the section we have examined, must originally have consisted of beds of reddish sand and mud, spread over the bed of that ancient Carboniferous sea once tenanted by the shells of the Napan limestone, much in the same manner that layers of mud are now deposited in the Bay of Fundy.

We have now, after passing over beds amounting altogether to the enormous thickness of 7636 feet, reached the commencement of the true coal measures, or that part of the section which was examined in detail by Sir Charles Lyell and the writer in 1852 and 1853. Owing to the comparative softness of the rocks of the last group described,

they have in many places been worn down nearly to the level of the beach, so that they cannot be very distinctly observed. Fortunately, however, just where the section becomes most interesting, the beds rise into a high cliff; and every one can be measured, and its mineral character and fossil contents observed, by any person who is content to labour diligently, and who is not too apprehensive that he may be buried under the falling cliffs, which, especially in the spring and in stormy weather, often send down very threatening showers of stones, and sometimes terrible landslips. This portion of the section, then, I shall give in detail, as one of the best specimens in the world of that wonderful series of fossiliferous beds constituting the great coal measures of the Carboniferous period; but before doing so we may complete this general view of the coast section.

Proceeding along the coast from the Joggins Mines, we find, toward Ragged Reef, coal measures still exposed, but with fewer and thinner beds of coal. At Ragged Reef there are again very important and valuable beds of grindstone. Beyond this all the way to Shoulie River, the coast shows sandstones and shales belonging to the Upper Coal Formation. In this we no longer find beds of coal; red sandstones and shales become more abundant, and the gray sandstones become coarse and pebbly, holding rounded fragments of quartz and syenite similar to that of the Cobequid Mountains. Fossils are not abundant; but *Calamites*, *Stigmaria*, *Lepidodendra*, and large petrified trunks of the pine trees of the coal formation, still appear. The general aspect of these beds is, to a great extent, similar to that of the Millstone-grit series, and this upper mass of barren coal measures may perhaps be defined to be the weight laid upon the coals to press them into the required consistency. The whole coal formation and its accompaniments may thus be compared to a huge botanical drying press. The millstone-grit is the lower board; the true coal measures represent the plants laid out between leaves of clay and sand instead of paper, and the Upper Coal Formation is the upper board and weight.

Toward Shoulie River the dip of the beds diminishes to 5°, and beyond this little stream, which seems to be in the middle of the synclinal, the dips change to N.E. (North 10° E. was observed on the bank of the river), and the beds are repeated with these north-easterly dips, until at Apple River they finally rest against those old rocks of Cape Chiegnecto, which form the limit of the Cumberland trough in this direction. I have not visited Apple River; but from Mr Donald Fraser, an explorer who visited this place under my direction, I learn that at Mill Brook, south-east of Apple River, there is a bed of coal one inch in thickness, and dipping to the north at a small angle. It

is associated with coarse sandstones and conglomerate, and probably belongs to the Lower Coal Measures or Millstone-grit series, the marine limestones being apparently absent. At least this is the interpretation I should be inclined to put upon the appearances, in connexion with the fact that along the north side of the Cobequids the marine Lower Carboniferous is either absent or overlapped by the higher members of the series in all the localities which I have explored.

In the first edition of this work, I gave in detail the thickness of 2819 feet explored by Sir Charles Lyell and myself in 1852, omitting the rest. I think it better in the present edition to give a condensed view of the whole, dwelling more particularly on the constitution and accompaniments of the beds of coal, and adopting the numbers and divisions both of the general section of Sir W. E. Logan and of that contained in my paper on the South Joggins already referred to, and in a more recent paper on the "Conditions of Accumulation of Coal." In excuse for occupying so much space with such details, I may plead that this list presents perhaps the most minute anatomy of a coal-field ever given to the public; and that the reader who takes the trouble to examine it with care, will thereby obtain a very accurate conception of the arrangement and accompaniments of beds of coal, and also of their probable mode of accumulation. The fossil plants and animals referred to are described in the chapters devoted to fossils.

It will be observed that in this sectional view the order is *descending*, or the reverse of that followed in the above general sketch.

Sectional View of the Carboniferous Rocks exposed in the Coast of the South Joggins, Cumberland (order descending).

The "*Divisions*" and the numbers attached to the several beds of coal or "Coal groups" are those of Sir W. E. Logan's section of 1845. The numbers of "Subdivisions" in Roman numerals are those of the author's section of 1852.

Division 1.

This extends along the coast from Shoulie River to the vicinity of Ragged Reef, being nearly horizontal at the former place and gradually assuming a decided south-west dip towards the latter. It is 1617 feet in vertical thickness, and constitutes the upper part of the "Upper Coal Formation." It occupies the centre of the great synclinal of the western part of the Cumberland coal area, and represents the newest beds of the Carboniferous system.

The rocks are thick-bedded white and gray sandstones, passing in

some places into conglomerates with quartz pebbles, and interstratified with reddish and chocolate shales. The sandstones predominate.

Fossils are not numerous in these beds. Those found are *Dadoxylon materiarium*, of which there are many drifted trunks in the sandstones, in a blackened and calcified condition, *Calamites Suckovii*, *C. Cistii*, *Calamodendron approximatum*, *Lepidodendron undulatum*, *Lepidophloios parvus*, and *Stigmaria ficoides*. As in the Upper Coal Formation of Pictou, trunks of Conifers and Calamites are the most abundant fossils.

Division 2.

This occurs at Ragged Reef and its vicinity. Its thickness is 650 feet. It constitutes the lower part of the Upper Coal Formation.

The rocks are white and gray sandstones with occasional reddish beds, and red and gray shales. The sandstones and shales are nearly in equal proportions. Underclays, or soils supporting erect plants, probably *Sigillariæ*, occur at two levels.

Fossils are not numerous. Those collected were *Sigillaria scutellata* and *Stigmaria ficoides*, *Calamites Suckovii*, *Sphenopteris hymenophylloides*, *Alethopteris lonchitica*, *Cyclopteris heterophylla*(?), *Beinertia Gœpperti*, and portions of the strobiles of two species of *Lepidophloios*, namely, *Lepidophyllum lanceolatum* and *L. trinerve*.

Division 3.

This extends in descending order from the vicinity of Ragged Reef to M'Cairn's Brook. Its thickness is 2134 feet. It includes the upper part of the "Middle Coal Formation," and is perhaps equivalent, in part at least, to the Upper Coal Measures of Great Britain, and to the Upper Coal Formation of American authors.

It includes 1009 feet of sandstone, almost all of which is gray, and 912 feet of gray and reddish shale and clay. It contains 22 beds of coal, all of small thickness, and most of them of coarse quality. Below, I give each bed of coal in detail, with its roof and floor and its fossils; and the intervening mechanical beds in brackets. The thickness of the roofs and floors is included in that stated for the intervening beds.

		ft.	in.
	(Carbonaceous shale, gray understone, with *Stigmaria* and gray shale)	7	0
Coal-group 1.......	Gray argillaceous shale.		
	Coal, 1 inch	0	1
	Gray argillaceous underclay, *Stigmaria*.		

The roof holds abundance of *Alethopteris lonchitica*. The coal is coarse and earthy, with much epidermal and bast

tissue,* vascular bundles of ferns, and impressions of *Sigillaria* and *Cordaites*. It is a compressed vegetable soil or dirt-bed, resting on an argillaceous subsoil with rootlets of *Stigmaria*.

		ft.	in.
	(Gray and reddish sandstones and gray and red shales with ironstone nodules)	281	6
Coal-group 2	Reddish argillaceous shale.		
	Coal, 1 inch; Carbonaceous shale, 4 inches; *Coal*, 1 inch	0	6
	Reddish underclay, *Stigmaria*.		

The coal is coarse, earthy, and shaly. It contains *Cordaites*, fern stipes, and bast tissue.

		ft.	in.
	(Reddish shale and gray sandstone, the latter seen in the cliff to thin out and give place to reddish shale)	53	9
Coal-group 3	Gray sandstone.		
	Coal, 1 inch	0	1
	Gray and reddish sandy understone, *Stigmaria*.		

The coal is coarse and shaly. No fossils were observed, except stumps and rootlets of *Stigmaria* in the underclay.

		ft.	in.
	(Reddish gray shale and gray sandstone)	6	0
Coal-group 4	Reddish gray shale.		
	Coal, 2 inches	0	2
	Gray and reddish argillaceous underclay, *Stigmaria*.		

The coal is coarse and earthy. No fossils were observed, except *Stigmaria* rootlets in the underclay. This and the last coal are to be regarded merely as fossil vegetable soils or dirt-beds.

		ft.	in.
	(Gray sandstone and gray and reddish shale. One underclay, and erect *Calamites* in the lowest bed)	239	6
Coal-group 5	Gray argillaceous shale.		
	Coal, 2 inches	0	2
	Gray argillo-arenaceous underclay, *Stigmaria*.		

The coal is filled with leaves of *Cordaites borassifolia*, dividing it into thin papery layers. The underclay has many large branching roots of *Stigmaria*.

		ft.	in.
	(Gray shale and sandstone)	19	0
Coal-group 6	Gray arenaceous shale.		
	Coal, 3 inches	0	3
	Gray argillo-arenaceous underclay, *Stigmaria*.		

This coal is composed of flattened bark of *Sigillaria*, of which there are many layers in the thickness of the bed. The species are not distinguishable.

* For explanation as to the nature of these and other structures in the coal, see chapter on "Plants of the Coal Formation."

		ft.	in.
	(Gray sandstone and shale. One underclay with *Stigmaria*)	12	6
Coal-group 7	Gray argillaceous shale. *Coal*, 1 inch. Gray argillaceous underclay, *Stigmaria*, 1 ft. 6 in. *Coal*, 2 inches. Gray argillaceous underclay, *Stigmaria*, 4 inches. *Coal*, 1 inch . . . . Gray argillaceous underclay, *Stigmaria*.	2	2

This is an alternation of thin coarse coals or fossil vegetable soils with *Stigmaria* subsoils. The roof-shale contains erect *Calamites*, which seem to have been the last vegetation which grew on the surface of the upper coal.

		ft.	in.
	(Gray and reddish sandstones and shales) . . .	73	0
Coal-group 8.......	Red and gray shale. *Coal*, 1 inch . . . . Gray hard underclay, *Stigmaria*.	0	1

This coal contains flattened trunks of *Sigillaria scutellata*, or an allied species, and of other *Sigillariæ*, also abundance of vascular bundles of ferns and portions of epidermal tissues of different plants.

		ft.	in.
	(Gray sandstone and red and gray shales. *Stigmaria* in the upper bed, and prostrate *Sigillaria* and *Cordaites* in some of the sandstones and shales) .	490	0
Coal-group 9.......	Gray argillaceous shale, ironstone nodules. *Coal*, 3 inches . . . . Argillo-arenaceous underclay, *Stigmaria*.	0	3

The roof of this coal holds prostrate *Sigillariæ* of three species and *Cordaites borassifolia*. The coal is hard and shining, with impressions of flattened *Sigillariæ*, also of *Cordaites*, *Asterophyllites*, *Carpolites*, and vascular bundles of ferns.

		ft.	in.
	(Underclay and reddish gray shale)	6	0
Coal-group 10......	Reddish gray shale. *Coal* and coaly shale, 8 inches. Gray argillaceous underclay, nodules of ironstone, and *Stigmaria*, 2 feet. *Coal*, stony and compact, 2 inches . . . . . Gray argillaceous underclay, *Stigmaria*.	2	10

The roof-shale has obscure impressions of plants, apparently petioles of ferns. The upper coal is thinly laminated and full of leaves of *Cordaites* and ferns, among which is *Alethopteris lonchitica*. The lower coal is compact, resembling cannel, and has many vascular bundles of ferns. It seems to be composed of herbaceous matter macerated in water and mixed with mud.

		ft.	in.
	(Gray sandstone and shale with nodules of ironstone)	23	0
Coal-group 11......	Gray argillaceous shale. *Coal*, shaly, 3 inches . . . . Arenaceous underclay, *Stigmaria*.	0	8

An erect ribbed *Sigillaria* appears in the roof-shale. The coal contains many flattened *Sigillariæ*, also *Trigonocarpa*, *Cordaites*, and vascular bundles of ferns.

		ft.	in.
	(Arenaceous understone with ironstone nodules and *Stigmaria*, and carbonaceous shale) . . .	7	9
Coal-group 12......	Carbonaceous shale.		
	Coal, 2 inches	0	2
	Argillaceous underclay, ironstone, and *Stigmaria*.		

This coal is hard and laminated, with many vascular bundles of ferns upon its surfaces.

		ft.	in.
	(Gray sandstone and gray argillaceous shale) . .	12	0
Coal-group 13.....	Gray argillaceous shale.		
	Coal, 7 inches	0	7
	Gray argillaceous underclay, ironstone, and *Stigmaria*.		

The roof contains erect stumps, not distinctly marked. The coal has indications of bark of *Sigillaria*, and is hard and shining, with a coarse earthy layer in the middle.

		ft.	in.
	(Gray shale)	7	0
Coal-group 14......	Gray shale, as above.		
	Coal, 4 inches.		
	Gray argillo-arenaceous underclay, ironstone, and *Stigmaria*, 1 foot 6 inches.		
	Coal, 2 inches	2	0
	Gray argillaceous underclay, ironstone, and *Stigmaria*.		

The upper coal has impressions of bark of trees and *Cordaites*, especially in its upper part.

		ft.	in.
	(Gray and reddish shale and gray sandstone, with Stigmarian soils at two levels)	52	0
Coal-group 15......	Gray shale.		
	Carbonaceous shale, 2 inches.		
	Argillaceous underclay, ironstone, and *Stigmaria*, 1 ft.		
	Coal, 1 inch	1	3
	Argillaceous underclay, ironstone, and *Stigmaria*.		

The upper shaly bed is a coal interlaminated with shale, which enables the nature of the coaly matter to be ascertained. It contains flattened *Sigillariæ* of several species, *Calamites*, *Cordaites*, *Cyperites*, leaves of *Sigillaria, and Lepidophylla*. The clay parting is the roof of the lower coal, and contains *Cyperites* and *Cordaites*. It has been converted into an underclay by the growth of *Sigillaria* upon it in the formation of the upper bed of coaly shale. The lower coal is compact, but showed an impression of a Calamite.

		ft.	in.
	(Gray sandstone and gray and reddish shale, ironstone nodules)	16	0
Coal-group 16......	Gray argillaceous shale.		
	Coal and carbonaceous shale, 2 inches . . .	0	2
	Reddish argillaceous underclay, ironstone, and *Stigmaria*.		

The roof supports an erect tree, a *Sigillaria*, 8 feet high and 1 foot in diameter. It is also rich in *Cyperites*,* *Cordaites*, and *Calamites*. The coal contains *Calamites* and also discigerous tissue of Conifers or *Sigillaria*.

		ft.	in.
	(Gray sandstones and reddish and gray shales, with several Stigmarian underclays, and coaly films or thin vegetable soils. One of the underclays supports large stumps of *Sigillaria*, with *Cyperites*, *Cordaites*, and *Lepidodendron* in the bed around their bases)	38	6
Coal-group 17......	Red and gray argillaceous shale. *Coal*, 1 inch. Gray argillo-arenaceous underclay, *Stigmaria*, 4 ft. *Coal*, 4 inches. Carbonaceous shale, 4 inches. *Coal*, 1 inch . . . . Gray arenaceous underclay, *Stigmaria*.	4	10

The upper layer of coal consists in part of leaves of *Cordaites*. The middle layer has much *Cordaites* and *Cyperites*.

		ft.	in.
	(Underclay and gray shale)	2	3
Coal-group 18......	Gray shale, as above. *Coal*, 3 inches . . . . Gray arenaceous underclay, *Stigmaria*.	0	3
	(Gray sandstone, and red and gray shale. Stigmarian soils at two levels)	26	0
Coal-group 19......	Reddish shale. *Coal*, 1 inch . . . . Red argillaceous underclay, *Stigmaria*.	0	1

The roof contains an erect *Sigillaria*. The coal and that of the previous bed were not well seen.

		ft.	in.
	(Gray sandstone and red and gray shales, with many drift-trunks and erect *Sigillariæ* at four levels) .	222	0
Coal-group 20......	Gray shale. *Coal*, 1 inch . . . . Red and gray underclay, *Stigmaria*.	0	1

This coal contains much *Cordaites*.

		ft.	in.
	(Gray and red shales and gray sandstone. One Stigmarian soil, and resting on it carbonaceous shale with *Cyperites*)	16	3
Coal-group 20a†...	Gray shale. *Coal*, 2 inches. Underclay, *Stigmaria*, 2 inches. *Coal*, 1 inch. Underclay, 1 inch, *Stigmaria*. *Coal*, 3 inches . . . . Argillaceous underclay, ironstone, and *Stigmaria*.	0	9

These coals contain mineral charcoal, showing scalariform and epidermal tissues. The coals are impure, and were probably concealed at the time of Sir W. E. Logan's visit.

* By this term I continue, for convenience, to designate the leaves of *Sigillariæ*.

† I designate in this way coal-groups not noticed in Logan's section.

		ft.	in.
	(Sandstone and red and gray shale, with one Stigmarian soil)	93	3
Coal-group 21	Red shale.		
	Coal and carbonaceous shale, 2 inches	0	2
	Gray argillaceous underclay, *Stigmaria*.		

In the bed above the roof-shale are erect *Calamites*. The coal is an uneven or irregular bed, and consists of flattened *Sigillariæ*, *Cyperites*, *Cordaites*, and ferns.

	(Gray and reddish sandstones and shales, with drift-trunks of *Dadoxylon materiarium*, *Sigillaria*, and *Calamites*)	334	0
Coal-group 22	Gray and red shale, nodules of ironstone.		
	Coal and carbonaceous shale, 2 inches	0	2
	Gray argillo-arenaceous underclay, *Stigmaria*.		

This coal consists of flattened bark of *Sigillaria* with *Cordaites* and vascular bundles of ferns. It contains also remains of fishes. Among these was found a tooth of *Ctenoptychius*. The underclay includes stumps of *Stigmaria*, as well as rootlets.

	(Gray sandstone and shale, with one Stigmarian soil supporting erect stumps of *Sigillaria*)	68	0
Total thickness of Division 3, according to Logan's measurements		2159	8

Division 4.

This division of the section extends from M'Cairn's Cove to the end of the high cliff beyond "Coal-mine Point." It corresponds to the lower part of the Middle Coal Formation, and probably to the Lower Coal Formation of some American authors. Its thickness, according to the measurements of Sir William E. Logan, is 2539 feet. It is remarkable for the prevalence of gray sandstones and gray and dark-coloured shales. It constitutes the part of the section re-examined by Sir C. Lyell and myself in 1852; and in the memoir which I subsequently published, it is divided into 27 groups or Subdivisions. For facility of reference, these groups are indicated by the Roman numerals in the following pages, beginning with the highest group, XXVII.

XXVII.

		ft.	in.
Coal-group 1	Bituminous limestone and calcareo-bituminous shale, 4 feet.		
	Coal, 1 foot	5	0
	Gray argillo-arenaceous underclay, *Stigmaria*.		

The roof has *Naiadites carbonarius* and *N. elongatus*, *Spirorbis carbonarius*, scales of *Rhizodus*, and obscure vegetable fragments. The coal contains flattened *Sigillariæ*, *Cordaites*, *Alethopteris lonchitica*, *Cyperites*, *Calamites Nova-scotica*, and many vascular bundles of ferns.

		ft. in.
	(Gray sandstone and shale, with six underclays and erect *Sigillaria* at two levels; also a thin shale with *Naiadites*, *Cythere*, *Calamites*, and *Cordaites*. One of the sandstones has scales and teeth of a large fish (? *Rhizodus*) and plants covered with *Spirorbis*)	50 0
Coal-group 2	Gray argillaceous shale. *Coal*, 1 inch. Clay, 3 inches. *Coal*, 1 inch. Clay, 1 inch. *Coal*, 1 inch. Shale, 4 inches. *Coal*, 3 inches	1 2
	Gray argillo-arenaceous underclay, *Stigmaria*.	

The roof has numerous vegetable fragments and flattened *Sigillariæ* and *Calamites*. One of the coals contains mineral charcoal, showing bast tissue, scalariform tissue, and fragments of epidermis. The lower coal has bark of *Sigillaria*, *Stigmaria*, and *Cyperites*, also numerous *Trigonocarpa* and vascular bundles of ferns. The clay partings and the underclay have obscure rootlets, probably of *Stigmaria*.

	(Arenaceous underclay and shale with remains of *Stigmaria*	4 0
Coal-group 3	Gray argillaceous shale. *Coal*, 3 inches	0 3
	Hard argillo-arenaceous underclay, *Stigmaria*.	

The roof has stumps of *Sigillariæ* erect, and with roots of *Stigmaria* descending among them from the bed above. The coal, which is coarse and earthy, has vascular bundles of ferns, scalariform vessels, bast tissue, and scales and spines of fishes (*Palæoniscus*, etc.), with coprolitic matter. The underclay shows abundant Stigmarian rootlets.

	(Underclay and gray arenaceous shale)	6 0
Coal-group 4	Gray argillaceous shale. *Coal*, 9 inches. Carbonaceous shale, 6 inches. *Coal*, 1 inch. Carbonaceous shale, 4 inches. *Coal*, 1 inch. Carbonaceous shale, 8 inches. *Coal*, 2 inches. Gray shale, 1 foot 7 inches. *Coal*, 8 inches	4 10
	Argillo-arenaceous underclay, *Stigmaria*.	

The roof contains obscure flattened plants. The coal is hard or shaly, with vascular bundles of ferns and bast tissue. The carbonaceous shales yield *Cordaites borassifolia*, *Alethopteris lonchitica*, *Calamites*, *Sigillaria*, and *Cyperites*. The gray shale

parting has erect stumps, apparently of *Sigillaria*. The upper shales and coals are very pyritous, and decompose when exposed to the weather—an indication that sea-water had access to these beds while the vegetable matter was still recent.

XXVI.

		ft.	in.
	(Gray argillaceous sandstone and red and gray shale, with two Stigmarian soils. Footprints, probably of *Dendrerpeton*, and rain-marks occur in these beds; and it was in one of them that Mr Marsh discovered the vertebræ of *Eosaurus Acadianus*)	82	0

XXV.

		ft.	in.
Coal-group 5	Bituminous limestone, 2 feet.		
	Coal, $\frac{1}{8}$ inch.		
	Argillo-arenaceous clay, *Stigmaria*, 6 inches.		
	Coaly shale, $\frac{1}{2}$ inch.		
	Gray argillo-arenaceous shale, ironstone nodules, *Stigmaria*, 1 foot 6 inches.		
	Coaly shale, 1 inch.		
	Gray shale, ironstone nodules, *Stigmaria*, 2 ft. 6 in.		
	Coal, 6 inches.	7	2
	Argillo-arenaceous underclay, *Stigmaria*.		

The bituminous limestone of the roof contains *Naiadites carbonarius* and *N. elongatus*, fish-scales, and cyprids. The upper layer of coal contains impressions of *Sigillaria* and *Lepidodendron*, on some of which are shells of *Spirorbis*. It has epidermal tissues, vascular bundles of ferns, and reticulated vessels. The coaly shales are of the nature of coarse coals, but with numerous thin layers of shaly matter. The lower coal contains petioles of ferns and *Cordaites* matted together, and numerous *Cardiocarpa*. The two thick clay partings and the underclay are Stigmarian soils.

XXIV.

		ft.	in.
	(Gray sandstone and chocolate and gray shales, with two Stigmarian soils)	147	0

XXIII.

		ft.	in.
Coal-group 6	Carbonaceous shale, passing downward into bituminous limestone, 1 foot 10 inches.		
	Coal, 4 inches	2	2
	Argillo-arenaceous underclay, *Stigmaria*.		

The roof contains *Naiadites carbonarius*, *Cythere*, *Spirorbis*, fish-scales, and coprolites. The coal is hard and laminated, and has on its surfaces leaves of *Cordaites* and vascular bundles of ferns. It is remarkable for containing scattered remains of a number of species of fishes belonging to the genera *Ctenop-*

tychius, *Diplodus*, *Palæoniscus*, and *Rhizodus*. The underclay has rootlets of *Stigmaria*, and the bed below this has large roots of the same.

		ft.	in.
	Gray sandstone and shale, the latter with nodules of ironstone. Erect trees at one level) . . .	30	0
Coal-group 7.......	Gray shale. *Coal*, 10 inches. Carbonaceous shale and coal, 7 inches. *Coal*, 2 feet 1 inch. Carbonaceous shale, 1 foot 6 inches.* *Coal*, 1 foot 6 inches . . . . Gray argillo-arenaceous underclay, *Stigmaria*.	6	6

This is the bed worked at the Joggins as the "Main Seam;" and I believe that it improves somewhat in mining it inward from the shore. The roof has afforded *Sigillaria catenoides* and other species, *Alethopteris lonchitica*, *Cordaites borassifolia*, *Lepidodendron elegans*, *Trigonocarpa*, *Naiadites*, *Spirorbis*, *Cythere*, fragments of insects. (?) The mineral charcoal contains bast tissue, scalariform, epidermal, and cellular tissues. In the compact part of the coal there is dense cellular and epidermal tissue. The roof is especially rich in *Cordaites*, sometimes with *Spirorbis* adherent.

		ft.	in.
	(Gray sandstone and shale, with many ironstone nodules in the shale, and erect *Sigillaria* and underclays at five levels. One of the latter has large stumps of *Stigmaria* and a thin coaly layer resting on it)	68	0
Coal-group 8.......	Gray shale with nodules of ironstone. *Coal*, 2 inches. Gray shale, 4 inches. *Coal*, 3 inches. Carbonaceous shale, 1 foot 3 inches. *Coal*, 1 inch. Argillaceous shale, ironstone nodules, 4 feet. *Coal*, 1 foot . . . . Dark argillo-arenaceous underclay, ironstone nodules, and *Stigmaria*.	7	1

The roofs of the first and second beds in this group are among the richest in fossils in the Joggins section. They have afforded *Pecopteris lonchitica*, *Cyclopteris*, *Cyperites*, *Cordaites borassifolia*, *Cardiocarpum fluitans*, *Sigillaria elegans*, *Lepidophloios Acadianus*, *Lepidodendron undulatum*, *Pinnularia*, *Trigonocarpa*, etc.; also *Diplostylus Dawsoni*,† *Eurypterus*, *Cythere*, *Naiadites*, and *Spirorbis* attached to plants. The

* Thins in mining to the N. E. The details of this seam have been corrected in this edition from a late report by Mr Rutherford.

† Salter, Quart. Journ. Geol. Soc., vol. xix. p. 77.

lower coal, called locally the "Queen's Vein," has in its mineral charcoal bast-cells, uniporous, rariporous, and multiporous wood-cells, scalcariform vessels, epidermal tissue, and vascular bundles of ferns, also stipes of ferns and bark of *Sigillaria*. The mineral charcoal occurs principally in a thick layer near the bottom of the bed. Its roof has trunks of *Lepidophloios*, *Lepidodendron*, and *Sigillaria*, fossilized by carbonate of iron. The upper part of the lowest underclay is dark and carbonaceous, with Stigmarian rootlets.

XXII.

		ft.	in.
	(Gray sandstones, gray and chocolate shales with ironstone nodules; three underclays and erect *Calamites* and *Sigillaria* in three beds)	110	0

XXI.

		ft.	in.
Coal-group 9	Gray shale and ironstone nodules.		
	Coal and coaly shale, 1 foot 3 inches	1	3
	Argillaceous underclay, *Stigmaria*.		

The roof contains erect *Sigillariæ*, *Stigmaria*, *Calamites*, and *Cordaites*. The coaly shale has fern-stipes and *Cordaites*. The coal itself is coarse and shaly, and has a layer of mineral charcoal containing bast and epidermal tissue. There are also in the coal remains of *Calamites* and *Cordaites*, and fragments, possibly, of insects.

		ft.	in.
	(Gray and reddish shales with nodules of clay-ironstone, and gray and reddish sandstone. One underclay supporting a coaly film, and erect trees at two levels)	28	6
Coal-group 10	Chocolate shale.		
	Coal and coaly shale, 2 inches.		
	Coaly shale, 6 inches.		
	Coal, 4 inches	1	0
	Argillo-arenaceous underclay, *Stigmaria*.		

The upper coal contains flattened *Sigillariæ* and *Stigmaria*. The lower bed is hard and unequal, with curved laminæ and obscure traces of petioles of ferns. The mineral charcoal has bast and scalariform tissues.

XX.

		ft.	in.
	(Red and gray shales and gray sandstones. Erect *Calamites* in one bed. Four underclays)	78	6

XIX.

		ft.	in.
Coal-group 11	Chocolate shale.		
	Coal and coaly shale, 8 inches	0	8
	Argillaceous underclay, *Stigmaria*.		

The roof has *Cordaites*, *Calamites*, and rootlets. The coal contains much mineral charcoal with the structure of dense

aporous bast tissue; it also contains *Cyperites* and many vascular bundles of ferns, with flattened trunks of *Sigillaria*.

		ft.	in.
	(Gray sandstones and argillaceous shale. Erect trees at two levels)	37	0
Coal-group 12......	Gray shale.		
	Coal and coaly shale, 1 foot	1	0
	Argillaceous underclay, ironstone, and *Stigmaria*.		

The roof contains erect *Sigillaria* and *Calamites*, also *Cordaites* with *Spirorbis* attached, and *Lepidodendron*. The coal has in one layer much *Cordaites*, in others it includes an immense number of specimens of *Sporangites papillata*; it has also bast tissue, epidermal tissue, and discigerous tissue.

	(Shale and sandstone, penetrated by Stigmarian rootlets, and containing in one of the shales *Lepidodendron*, *Sigillaria*, and *Carpolithes*) . . .	13	0
Coal-group 13......	Gray shale.		
	Coal and coaly shale	0	6
	Argillaceous underclay, *Stigmaria*.		

The roof has much *Cordaites*. The shaly portions of the coal contain *Sigillaria elegans*, *Alethopteris lonchitica*, *Cordaites borassifolia*, *Lepidodendron*, *Diplotegium*, *Trigonocarpum*, *Stigmaria*, and *Sporangites glabra*, also vascular bundles of ferns and bast tissue.

XVIII.

	(Gray and red shales and gray sandstone; one of the latter with erect *Calamites* and *Sigillariæ*. One underclay)	69	4

XVII.

Coal-group 13*a*....	Gray shale.		
	Coal, 8 inches	0	8
	Argillaceous underclay, *Stigmaria*.		

The roof has *Cordaites* and many decayed stipes. The coal has *Cordaites* and vegetable fragments.

XVI.

	(A very thick sandstone with shales. Erect *Calamites*, footprints of reptiles, and rain-marks) .	57	0

XV.

Coal-group 14......	Gray shales with ironstone.		
	Coal, 3 inches.		
	Coaly shale, 2 inches.		
	Coal, 8 inches.		
	Underclay, *Stigmaria*, 6 feet.		
	Coaly shale, 4 inches.		
	Underclay, *Stigmaria*, 1 foot.		
	Coaly shale, 8 inches.		
	Coal, 2 inches	8	10
	Argillo-arenaceous underclay, *Stigmaria*, and ironstone.		

On the roof of the upper coal was a fine ribbed *Sigillaria* with Stigmarian roots. In the roof and shaly partings are *Sigillaria Brownii*, *S. Schlotheimiana*, and other species, *Stigmaria*, *Lepidodendron*, *Calamites*, *Cordaites*, *Sporangites glabra*, *Alethopteris lonchitica*, *Sphenopteris latifolia*, *Pinnularia*, and *Cyperites*; also *Cythere*, *Naiadites*, and fragments of reptilian (?) bones. The coal is pyritous, and exhibits impressions of the bark of *Sigillaria*; it contains also bast tissue, scalariform tissue of *Sigillaria* and multiporous tissue of *Sigillaria* and *Calamodendron*.

		ft.	in.
	(Sandstone and shale, erect *Calamites* and *Sigillaria* with *Stigmaria*. The erect trees contain reptilian remains of the genera *Dendrerpeton*, *Hylonomus*, and *Hylerpeton*; also *Pupa vetusta*, *Xylobius Sigillariæ*, and remains of insects)	10	0
Coal-group 15......	Coaly shale.		
	Coal, 6 inches	0	6
	Arenaceous underclay, *Stigmaria*.		

The erect trees above mentioned are rooted in the roof of this coal. It contains *Cyperites*, *Lepidophylla*, *Trigonocarpa* of two species, *Sphenophyllum*, *Alethopteris lonchitica*, *Cordaites*, and *Asterophyllites*. There are shells of *Spirorbis* on some of the plants. The coal contains layers of bark of *Sigillaria* and leaves of *Cordaites*, and much bast tissue, with scalariform, uniporous, and reticulated tissues, probably of *Sigillaria*.

	(Sandstones and shales; erect *Calamites* and *Stigmaria*)	21	0
Coal-group 15*a*....	Gray shale.		
	Coal, 4 inches	0	4
	Argillaceous underclay, *Stigmaria*.		

The roof contains *Calamites*, *Sigillaria*, *Alethopteris lonchitica*, *Pinnularia*, *Lepidodendron*, *Cyperites*, *Sporangites*, and *Spirorbis*. One *Sigillaria* extends 30 feet without branching. The roof supports an erect tree. The coal is filled with flattened stems of *Sigillaria* lying in different directions, also flattened *Lepidodendra*; and in its mineral charcoal it has beautiful porous and scalariform tissues.

XIV.

	(Gray sandstone and gray and red shales. Many prostrate trunks of *Sigillaria* and *Lepidodendron*, one underclay, and erect trees at one level) .	68	0
Coal-group 16......	Shale with the aspect of underclay.		
	Coal and coaly shale 6 inches	0	6
	Argillo-arenaceous underclay, ironstone, and *Stigmaria*.		

This bed was not well exposed, and afforded no fossils.

		ft.	in.
	(Gray sandstone and shale with one underclay) .	25	6
Coal-group 17......	Gray shale.		
	Coal and coaly shale 3 inches	0	3
	Argillo-arenaceous underclay, *Stigmaria*.		

The roof has vegetable fragments and *Cordaites*. The coal is hard and coarse, and contains flattened broad-ribbed *Sigillaria*, *Cordaites*, and vascular bundles of ferns.

		ft.	in.
	(Shale and sandstone, erect trees at one level) . .	31	3

XIII.

		ft.	in.
Coal-group 18......	Gray shale.		
	Coal 8 inches	0	8
	Argillo-arenaceous underclay.		

The roof has an erect *Sigillaria*. The coal is shaly and laminated. It contains much *Cordaites*, also *Lepidodendron*, *Calamites*, and *Alethopteris lonchitica*. In one layer there are *Naiadites*, *Spirorbis*, and scales of fishes.

		ft.	in.
	(Gray sandstone and shale in several beds, *Stigmaria*)	29	0
Coal-group 19......	Argillaceous shale.		
	Coaly shale, 4 feet.		
	Bituminous limestone, 2 feet 6 inches.		
	Coal, 1 inch	6	7

The roof has *Naiadites*, scales and teeth of fishes, *Cythere*, and *Spirorbis*. The coal is hard and coarse, with vascular bundles of ferns and prostrate *Sigillariæ*.

		ft.	in.
	(Shale and sandstone)	20	6
Coal-group 20......	*Coaly shale*, 1 foot.		
	Bituminous limestone, 1 foot 6 inches.		
	Coal and clay partings, 2 feet 4 inches	4	10

The roof has *Naiadites*, *Spirorbis* attached to plants, and small rhombic fish-scales. The coal alternates with limestone at the top, and contains remains of *Sigillaria*, *Sporangites*, and vascular bundles of ferns.

		ft.	in.
	(Sandstone, and gray and black shale with coaly layers)	21	0
Coal-group 21......	Gray shale and calcareo-bituminous shale.		
	Coal, 10 inches	0	10
	Argillaceous underclay, *Stigmaria*.		

The roof has obscure vegetable fragments and *Naiadites*. The coal contains vascular bundles of ferns, bast tissue, uniporous cells, and scalariform and reticulated vessels.

		ft.	in.
	(Gray sandstone and shale. Two underclays) .	20	0
Coal-group 22......	Gray shale.		
	Coal and coaly shale, 2 inches	0	2
	Argillaceous underclay, *Stigmaria*.		

This bed was not well exposed.

		ft.	in.
	(Sandstone and shale, with one erect tree and two underclays)	12	0
Coal-group 23......	Coaly and gray shale.		
	Coal and coaly shale, 4 inches.		
	Bituminous limestone, 4 inches.		
	Coal and coaly shale, 7 inches	1	3
	Argillo-arenaceous underclay, *Stigmaria*.		

The roof has an erect tree, also *Cordaites* and *Spirorbis*. The shale and bituminous limestone contain *Sigillaria* and *Lepidophloios*, also many large furrowed trunks, probably old *Sigillariæ* or *Lepidodendra*.

XII.

	(Sandstone, shale, and calcareo-bituminous shale, with three underclays)	26	0
Coal-group 24......	Calcareo-bituminous shale.		
	Coal and coaly shale, 1 inch	0	1
	Argillo-arenaceous underclay, *Stigmaria*.		

This bed was not exposed.

	(Underclay and shale)	5	0
Coal-group 25......	Gray shale.		
	Coal and coaly shale, 8 inches	0	8
	Argillo-arenaceous underclay, *Stigmaria*.		

The roof has *Alethopteris lonchitica*, *Cordaites*, and petioles of ferns. The coal shows bast tissue and remains of *Sigillaria* and *Calamites*.

	(Gray sandstone and shale, with erect *Sigillariæ* at four or five levels, and two Stigmarian underclays)	117	8
Coal-group 26......	Gray shale.		
	Coaly shale, 4 inches	0	4
	Argillo-arenaceous underclay, *Stigmaria*.		

This bed was not exposed.

	(Shale and sandstone, with *Stigmaria*)	13	0
Coal-group 27......	Gray shale.		
	Coal, 3 inches	0	3
	Argillo-arenaceous underclay, *Stigmaria*.		

This bed was not well exposed.

	(Gray sandstone and shale, with bituminous shale and limestone, and erect *Calamites*)	64	0

XI.

Coal-group 28......	Calcareo-bituminous shale.		
	Coal and coaly shale, 7 feet.		
	Underclay, *Stigmaria*, 4 feet.		
	Coaly shale, 1 foot.		
	Coal, 6 inches	12	6
	Arenaceous underclay, *Stigmaria*.		

This group is a series of thin coaly layers and underclays. The roof has *Naiadites carbonarius* and *N. elongatus*, also *Cythere* and scales of fishes. The coal contains bast tissue

and different kinds of scalariform and epidermal tissues. In the lower bed is a coaly stump and an irregular layer of mineral charcoal, arising apparently from the decay of similar stumps.

		ft.	in.
	(Gray and carbonaceous shale and gray sandstone)	29	0
Coal-group 29	Underclay, *Stigmaria*.		
	Coal, and coaly shale, 5 feet.		
	Underclay, 6 feet.		
	Coal, coaly shale, and ironstone, 6 feet.		
	Coal, 4 feet	21	0
	Argillaceous underclay, *Stigmaria*.		

This is a group of unusually thick beds, indicating long quiescence. The roof includes laminæ of coal, some of them composed of the bark of *Sigillaria catenoides*, also an erect *Sigillaria* rooted in the coal below. The coal and coaly shale exhibit remains of *Sigillaria*, *Cordaites*, *Lepidophyllum*, and *Cyperites*; and one layer has many hard pyritized fragments of wood. The mineral charcoal has vascular bundles of ferns, coarse scalariform tissue, and porous tissue. The underclay rests on a bed with *Naiadites*.

		ft.	in.
	(Underclay, *Stigmaria*, and gray and carbonaceous shales)	18	0
Coal-group 29*a*	Shale and coaly layers.		
	Coal, 4 feet	4	0
	Argillaceous underclay, *Stigmaria*.		

The roof has obscure fragments of plants and stumps in the state of mineral charcoal. The coal shows impressions of flattened trunks, probably *Sigillariæ*. This coal contains a great variety of tissues, especially bast and scalariform of different kinds, and epidermal. My measurements in this part of the section differ somewhat from those of Sir W. E. Logan, who, I suppose, had not a good opportunity of examining the two last coals. The coal 29*a* is now mined by an adit from the shore, called the "New Mine."

		ft.	in.
	(Sandstone and shale. One sandstone has many large erect *Sigillariæ*, some of them with rough and furrowed bark)	35	0
Coal-group 30	Argillaceous shale and ironstone.		
	Coal, 4 inches.		
	Underclay, dark-coloured, 2 feet.		
	Coal and coaly shale, 2 inches.		
	Coal, 3 inches.		
	Coaly shale, 2 inches.		
	Coal, 1 inch	3	0
	Soft argillaceous underclay, *Stigmaria*.		

The roof has bark of *Sigillaria* preserved in ironstone. The coal is pyritous, and consists of layers of mineral charcoal

alternating with bright coal; it has obscure impressions of plants and bast tissue in the mineral charcoal.

X.

		ft.	in.
	(Gray shale and sandstone. One underclay, and erect *Calamites* and *Sigillaria* at two levels)	19	0
Coal-group 31......	Gray sandstone.		
	Coal and coaly shale, 1 foot.		
	Underclay, *Stigmaria*, 1 foot.		
	Coaly shale, 6 inches.		
	Coal, 2 inches	2	8
	Argillaceous underclay, *Stigmaria*.		

The roof contains *Sigillariæ*, and the coal has flattened impressions of the same. This coal is remarkable as having a roof of sandstone. Its underclay is also peculiar. It is about 9 feet in thickness, and contains *Stigmaria* and nodules of ironstone throughout. It rests on a bituminous limestone containing *Naiadites* and scales of fishes, and also large roots of *Stigmaria* evidently *in situ*. This bed gives more colour to the idea of *Stigmaria* having grown under water than any other bed at the Joggins. I believe, however, that it merely implies the drying-up of a pond or creek into a swamp, subsequently inundated at intervals with muddy water.

		ft.	in.
	(Underclay and bituminous limestone, succeeded by sandstone and shale)	27	8
Coal-group 32......	Gray shale.		
	Coal, and coaly shale, 2 feet 4 inches	2	4
	Argillo-arenaceous underclay, *Stigmaria*.		

This is a series of thin coaly bands alternating with shales. The roof contains trunks of *Sigillaria*, *Cordaites*, *Alethopteris*, and *Cyperites*. The coal has numerous flattened trunks of *Sigillaria*.

		ft.	in.
	Gray and reddish sandstone and shale. Five underclays, one with a film of coal and erect *Sigillariæ* at two levels)	149	0
Coal-group 33......	Coaly shale.		
	Coal, 1 inch	0	1
	Argillaceous underclay, *Stigmaria*.		

The roof has flattened trunks and vegetable fragments. The coal is a mere soil, with remains of *Sigillaria* and *Cordaites*, and vascular bundles of ferns.

		ft.	in.
	(Red and gray sandstone and shale)	45	0
Coal-group 33*a*....	Gray shale.		
	Coal and coaly and gray shale (underclay).		
	Argillaceous underclay, *Stigmaria*.		

These layers, though not of sufficient importance to be measured as coal-bands, are most interesting as furnishing

examples of what may be termed rudimentary coal-beds. Each layer is plainly composed of prostrate trunks of *Sigillaria* resting on Stigmarian underclay, and mixed with *Cordaites*, *Alethopteris lonchitica*, and vascular bundles of ferns. In one layer is a stump in the state of mineral charcoal. In another there are coprolites, scales of fishes, *Spirorbis*, and fragments of Crustaceans. In a reddish shale above these beds there is a patch of gray sandstone interlaced with Stigmarian roots, as if the sand had been prevented from drifting away by a tree or stump.

		ft.	in.
	(Reddish and gray sandstones and shales, with three or more underclays, having their coaly layers holding *Sigillaria*. Erect *Sigillariæ* at two levels)	246	0
Coal-group 34......	Underclay, with ironstone and *Stigmaria*. *Coal*, and coaly shale, 2 inches. Underclay, with ironstone and *Stigmaria*, 4 feet. *Coal*, and coaly shale, 2 inches . . . . . Argillo-arenaceous underclay, *Stigmaria*.	4	4

Only obscure vegetable fragments were observed.

	(Gray and reddish sandstone and shale, with *Stigmaria*)	13	10
Coal-group 35......	Underclay with *Stigmaria*. *Coaly shale*, 3 inches . . . . Red and greenish underclay, a few rootlets.	0	3

The coaly shale contains many leaves of *Cordaites borassifolia*.

	(Red, gray, and dark shale, sandstone, and bituminous limestone. Three underclays and erect trees at one level)*	67	9

IX.

Coal-group 36......	Bituminous limestone. Coaly shale and *Coal*, 3 inches. Reddish shale and ironstone, 2 feet 6 inches. *Coal*, 3 inches . . . . Argillaceous underclay, *Stigmaria*.	3	0

The roof has *Stigmaria in situ*, and has been a soil or underclay. It also contains *Cythere*, fish-scales, coprolites, and *Spirorbis*. In the upper coaly shale are prostrate carbonized trunks.

	(Reddish and gray shale, sandstone, and bituminous limestone)	21	6
Coal-group 37......	Bituminous limestone and shale. *Coal*, 4 inches. Underclay, 1 foot 6 inches. *Coal*, 6 inches. Underclay, 1 foot. Bituminous limestone, 3 inches. Shale, 3 inches. *Coal*, 1 inch . . . . Underclay with *Stigmaria*.	3	11

* The lower 22 feet are included in Subdivision IX. of my former Section.

The roof has *Stigmaria*, also fish-scales, *Naiadites*, and *Cythere*. The shales are pyritized. The coal shows only obscure fragments of plants; but *Sigillariæ* in the state of ironstone occur in some of the clays.

		ft.	in.
	VIII.		
	(Red and gray sandstone and shale. Two underclays. Many shells of *Pupa vetusta* and *Conulus priscus* occur in one of these, about 42 feet below the last coal)	83	0
	VII.		
Coal-group 38......	Calcareo-bituminous shale. *Coal*, 1 inch. Bituminous limestone, 6 inches. *Coal*, 2 inches. Underclay passing into chocolate shale, *Stigmaria*.		

The bituminous limestone and shale contain *Cythere*, *Naiadites elongatus* and *N. carbonarius*, coprolites, *Spirorbis*, and *Stigmaria*. The lower coal has *Sigillaria elegans*, *S. scutellata* (?), *S. Brownii*, *Alethopteris lonchitica*, *Cordaites borassifolia*, and vascular bundles of ferns.

		ft.	in.
	VI.		
	(Red and gray shales and sandstones, and one gray limestone with *Cythere*. One underclay. Many drift trunks, among which are *Sigillaria* and *Lepidophloios*)	123	6
	V.		
Coal-group 39......	Red and gray shale, with ironstone. *Coal*, ½ inch . . . . Gray underclay, with *Stigmaria*, resting on bituminous limestone, with *Stigmaria* and *Cythere*.	0	0½

This thin coal consists of a layer of flattened trunks, probably of *Sigillaria*, with a quantity of mineral charcoal.

		ft.	in.
	IV.		
	(Red and gray shales. One bed with erect *Calamites*, another with erect *Sigillaria*)	65	4
	III.		
Coal-group 40......	Gray shale and ironstone. Bituminous limestone and shale, with coaly films, 7 inches. Underclay, 1 foot. *Coal*, 1 inch. Coaly shale, 3 inches. Underclay, 1 foot. Bituminous limestone, 6 inches. *Coal* and coaly shale, 2 inches . . . . . Argillaceous underclay, ironstone, and *Stigmaria*.	3	7

The bituminous limestone and shale have *Naiadites*, *Cythere*, *Spirorbis*, scales of fishes, and coprolites, and a large spine of *Gyracanthus*, also roots of *Stigmaria*. The upper underclay holds carbonized erect trunks. The lower coal has vascular bundles of ferns and *Cordaites*. The roof supports erect stumps.

		ft.	in.
	(Underclay, with ironstone nodules)	5	0
Coal-group 41......	Underclay as above. Calcareo-bituminous shale and films of *Coal* Argillaceous underclay, *Stigmaria*.	3	4

The bituminous limestone has *Naiadites carbonarius*, *Cythere*, coprolites, and *Spirorbis*. The roof has prostrate *Sigillariæ* converted into coaly layers. The underclay has distinct stumps of *Stigmaria*.

		ft.	in.
	(Shales with *Stigmaria* and ironstone, sandstones, bituminous limestone, and carbonaceous shale at bottom)	14	4
Coal-group 42......	Bituminous limestone. *Coal*, 3 inches. Shale, 1 foot. *Coal*, 1 foot. Underclay, *Stigmaria*, 1 foot. *Coal*, 2 inches. Dark argillaceous underclay, *Stigmaria*.	3	5

The roof contains *Naiadites*, *Cythere*, and coprolites. The coal is coarse, pyritous, and shaly, and has bark of *Sigillaria*, *Calamites*, and vascular bundles of ferns. It seems to be the edge of a bed, as it thins rapidly in the direction of the bank, or to the east.

II.

		ft.	in.
	(Reddish shale and sandstone with one underclay)	35	0
Coal-group 43......	Reddish underclay with *Stigmaria*. *Coaly shale*, 1 inch Reddish underclay, *Stigmaria*.	0	1

This bed diminishes to a mere film towards the bank.

I.

		ft.	in.
	(Reddish, gray, and dark shales and sandstone, *Stigmaria* in some beds, and erect *Sigillariæ*, *Lepidodendra*, (?) and *Calamites* at one level)	63	0
Coal-group 44......	Gray shale with ironstone. Bituminous limestone and shale with ironstone, 10 ft. 1 in. *Coal*, ½ inch. Bituminous limestone, *Stigmaria*, ½ inch. *Coal*, 5 inches. Bituminous limestone, *Stigmaria*, 2 inches. *Coal*, 1 inch. Bituminous limestone, *Stigmaria*, 2 inches. *Coal*, ½ inch Argillo-arenaceous underclay, traces of rootlets.	11	0½

The bituminous limestone has scales of fishes, *Spirorbis*, and *Cythere*. The coal has *Cordaites* and vascular bundles of ferns.

		ft.	in.
	(Red and gray sandstone and shale. One underclay, and erect *Calamites* at one level)	98	6
Coal-group 45......	Reddish shale. Carbonaceous shale, 10 inches. *Coaly matter*, $\frac{1}{2}$ inch. Hard underclay, *Stigmaria*, 2 feet. *Coaly matter*, $\frac{1}{2}$ inch. Underclay, *Stigmaria*, 7 feet. *Coal*, 3 inches . . . . Arenaceous underclay, *Stigmaria*.	10	2

In the roof of the lower coal is an erect tree. The coal has vascular bundles of ferns, remains of fern-leaves, and bast tissue. The underclay has many coaly films, apparently flattened bark of trees.

		ft.	in.
	Reddish and gray sandstone and shale . . .	5	6
Total thickness of Division 4, according to Logan's measurements		2539	1

Division 5.

This consists of reddish shales and red and gray sandstones. It contains no coal, and is poor in fossils, only a few drifted trunks appearing in the section. It corresponds to the upper part of the Millstone-grit series. Its thickness, according to the measurements of Sir W. E. Logan, is 2082 feet.

Division 6.

This may be regarded as the middle of the Millstone-grit series. It constitutes a sort of false coal formation, separated from the Middle Coal Formation by the barren beds of Division 5. It contains nine small or rudimentary coal-beds, which, however, are not well seen in the section, and have afforded few facts of interest. It has many thick and coarse sandstones and much red shale, with comparatively few dark-coloured beds. Its total thickness is stated by Sir W. E. Logan at 3240 feet.

Though this group contains little coal, it is to be observed that it has many underclays, indicating soils which supported forests of *Sigillaria*, and that erect *Sigillariæ* occur very near the base of the division. The absence of important beds of coal is therefore due to the local physical conditions, and not to the want of the necessary vegetation.

		ft.	in.
	(Sandstones and shales with many drifted trunks of *Dadoxylon*)	539	7
Coal-group 1.......	Blackish gray shale. Calcareous shale, 1 foot. Black shale, 3 feet. *Coaly shale*, 2 inches . . . . Argillo-arenaceous underclay, *Stigmaria*.	4	2

		ft.	in.
	(Red and gray sandstone and shale and concretionary limestone, trunks of *Dadoxylon* and other trees. One underclay)	160	1
Coal-group 2	Gray shale.		
	Coaly shale, 1 inch	0	1
	Reddish and gray underclay, *Stigmaria*.		
	(Series of underclays with *Stigmaria*. The beds are reddish or gray, and arenaceous)	19	1
Coal-group 3	Reddish shale.		
	Coaly shale, 1 inch.		
	Greenish shale, 6 inches.		
	Coaly shale, 1 inch.		
	Greenish shale, 2 feet 6 inches.		
	Coaly shale, 3 inches.		
	Greenish shale, 1 inch.		
	Coal and coaly shale, 3 inches	3	9
	Argillo-arenaceous underclay, *Stigmaria*.		

The coal contains bast tissue and reticulated, porous, and scalariform tissues of *Sigillaria* and *Calamodendron*.

		ft.	in.
	(Series of underclays as before)	12	0
Coal-group 4	Underclay, *Stigmaria*.		
	Coal and coaly shale, 3 inches	0	3
	Argillo-arenaceous underclay, *Stigmaria*.		
	(Series of underclays as before)	24	0
Coal-group 5	Gray shale.		
	Coaly matter, ½ inch	0	½
	Greenish underclay, *Stigmaria*.		
	(Underclay and sandstone, the latter with an erect *Sigillaria*)	10	0
Coal-group 6	Sandstone (erect *Sigillaria* as above).		
	Coaly shale, 3 inches	0	3
	Argillo-arenaceous underclay, *Stigmaria*.		
	(Fifteen feet of underclay, under which a thick sandstone with great quantities of drifted trunks of *Dadoxylon* and *Sigillaria*. Below this alternations of gray and red sandstone and shale)	210	10
Coal-group 7	Gray sandstone.		
	Bituminous limestone, 3 inches.		
	Gray shale, 3 feet.		
	Gray limestone, 2 inches.		
	Coaly shale, 6 inches.		
	Bituminous limestone, 3 inches.		
	Coaly shale, 1 foot.		
	Coal, 1 inch	5	3
	Argillo-arenaceous underclay, *Stigmaria*.		

The lower bituminous limestone contains *Naiadites ovalis*, *Cythere*, and scales of Lepidoid fishes. The lower coal has much *Cyperites* and bark of *Sigillaria*, also bast tissue in mineral charcoal.

		ft.	in.
	(Thick beds of gray sandstone and gray shale, with drifted trunks of *Dadoxylon*, *Sigillaria*, and *Calamites* and leaves of *Cordaites*)	532	0
Coal-group 8	Gray shale.		
	Coal, ½ inch	0	½
	Argillo-arenaceous underclay, *Stigmaria*.		

This coal is laminated, the laminæ being bark of *Sigillariæ*. The underclay is very rich in *Stigmaria*.

		ft.	in.
	Gray sandstone with gray and red shale. Many drifted trunks of *Sigillaria* and *Calamites*, and an erect *Sigillaria* in the lowest bed of sandstone)	1224	0
Coal-group 9.	Gray shale.		
	Coaly matter and carbonaceous shale	0	2
	Argillo-arenaceous underclay, *Stigmaria*, and ironstone.		
	(Gray and red sandstone and shale and calcareous bands, some of them bituminous. Near the middle a thick band of laminated black shale with *Naiadites lævis*, *Cyperites*, and *Lepidostrobus*. Drifted *Calamites* in the sandstones)	496	4
Total thickness, according to Logan		3240	9

Division 7.

This division consists principally of red and chocolate shales with red and gray sandstone, arenaceous conglomerates, and thin beds of concretionary limestone. It may be regarded as the base of the Millstone-grit formation. Its thickness is stated by Sir W. E. Logan at 650 feet.

No fossils, other than carbonized fragments of plants, have been found in this division.

Division 8.

This division consists of reddish shales with greenish and red sandstone, gray shale, gray compact limestone, and gypsum. It may be regarded as the upper part of the Lower Carboniferous formation; and almost immediately under its lowest beds there are marine limestones with *Productus cora* and other characteristic Lower Carboniferous fossils.

Only fragments of plants, often replaced by sulphuret of copper, have been found in this division. Its thickness is stated by Logan at 1658 feet.

The number of coals reckoned may vary according to the manner in which the several layers are grouped; but as arranged in the above sectional list, it amounts to eighty-one in all. Of these, 23 are found in Division 3 of Logan's section, being the upper member of the Middle Coal Formation; 49 are found in Division 4 of Logan's section, being the lower member of the Middle Coal Formation; 9 occur in Division 6 of Logan's section, or in the equivalent of the Millstone-grit.

CHAPTER XII.

THE CARBONIFEROUS SYSTEM—*Continued.*

CUMBERLAND COAL-FIELD, *continued*—EXPLANATION OF JOGGINS SECTION—ANIMAL REMAINS OF THE COAL MEASURES.

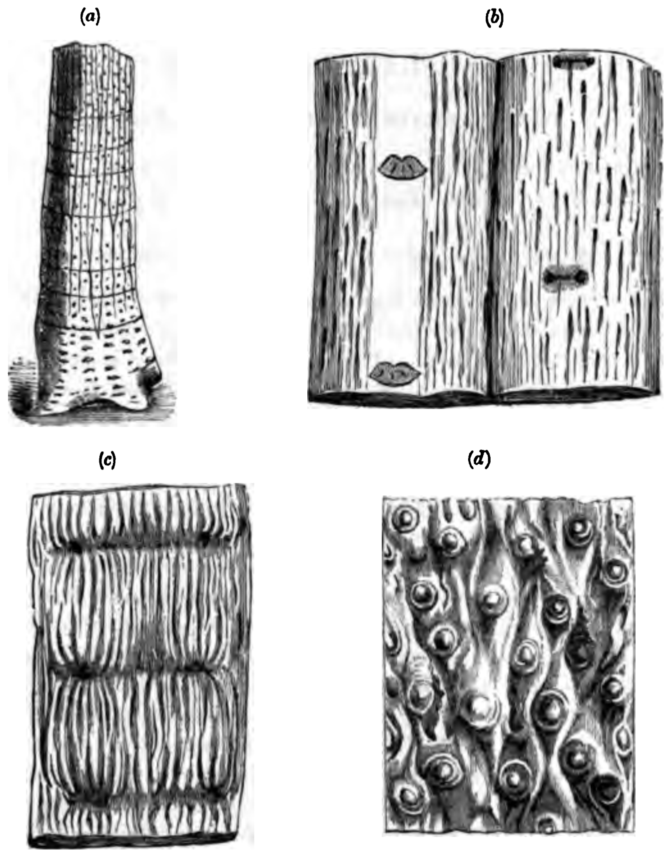
Explanatory Remarks on the Joggins Section.

In the section in the preceding chapter the reader will observe the words "Underclay, *Stigmaria*," frequently recurring; and over nearly every underclay is a seam of coal. An underclay is technically the bed of clay which underlies a coal-seam; but it has now become a general term for a *fossil soil*, or a bed which once formed a terrestrial surface, and supported trees and other plants; because we generally find these coal underclays, like the subsoils of many modern peat-bogs, to contain roots and trunks of trees which aided in the accumulation of the vegetable matter of the coal. The underclays in question are accordingly penetrated by innumerable long rootlets, now in a coaly state, but retaining enough of their form to enable us to recognise them as belonging to a peculiar root, the *Stigmaria*, of very frequent occurrence in the coal measures, and at one time supposed to have been a swamp plant of anomalous form, but now known to have belonged to an equally singular tree, the *Sigillaria*, found in the same deposits (Fig. 30). The *Stigmaria* has derived its name from the regularly arranged pits or spots left by its rootlets, which proceeded from it on all sides. The *Sigillaria* has been named from the rows of leaf-scars which extend up its trunk, which in some species is curiously ribbed or fluted. One of the most remarkable peculiarities of the stigmaria-rooted trees was the very regular arrangement of their roots, which are four at their departure from the trunk, and divide at equal distances successively into eight, sixteen, and thirty-two branches, each giving off, on all sides, an immense number of rootlets, stretching into the beds around, in a manner which shows that these must have been soft sand and mud at the time when these roots and rootlets spread through them.

It is evident that when we find a bed of clay now hardened into

stone, and containing the roots and rootlets of these plants in their natural position, we can infer, 1*st*, that such beds must once have been

Fig. 30.—*Stem, Leaf-scars, and Stigmaria Roots of Sigillaria—South Joggins.*



(*a*) *Sigillaria Brownii.*—Stem reduced.
(*b*) Portion, natural size, near the top.
(*c*) Do. do., near the base.
(*d*) Portion of *Stigmaria* root, natural size, with scars of rootlets.

in a very soft condition; 2*dly*, that the roots found in them were not drifted, but grew in their present positions; in short, that these ancient roots are in similar circumstances with those of the recent trees that underlie the Amherst marshes. In corroboration of this, we shall find, in farther examination of this section, that while some

of these fossil soils support coals, others support erect trunks of trees connected with their roots and still in their natural position.

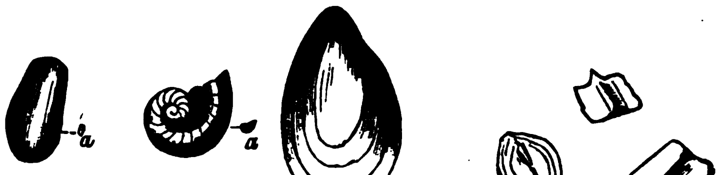
Believing the underclays to have been soils, we find similar reasons to conclude that the coal-seams were originally vegetable matter, which accumulated in the manner of peat; and on examining the coal minutely, we often find distinct evidences that it is composed in part of woody fragments, sometimes retaining their structure in sufficient perfection to enable the kind of wood to which they belonged to be ascertained. These appearances are most distinctly seen in the coarser and more impure coals, and in the bands of clay and ironstone which occur within the coal-seams. In the more pure coals, the vegetable matter has sometimes been reduced by chemical change and pressure into an almost homogeneous mass. It will be observed that in the section I have indicated the kinds of vegetable matter which may be observed in the several coals; and I shall have occasion to return to this subject in the sequel.

The lowest coal-bed in Group 44, Subdivision I, Division 4, of the above section, has an underclay or soil four feet in depth, and supporting a layer of vegetable mould which has been compressed into half an inch of coal. Above the coal rests a very different description of rock, one of those hard dark-coloured limestones already referred to. It is filled with innumerable little shells of minute crustaceous animals of the genus *Cythere*, the modern representatives of which reside in countless numbers in ponds and river estuaries and in the sea, and are most voracious devourers of dead animal substances. Our coal-bog therefore became, from some cause, probably subsidence, a pond or lagoon, in which *Cythere* and other aquatic animals must have existed for some time before their remains could accumulate in sufficient quantity to form these two inches of hard bituminous limestone. The *Cythere*-inhabited waters, however, were dried up, and on the rich marly soil grew another forest, whose rootlets may be seen finely preserved in the limestone; and the result was a thicker seam of coal than the first, succeeded by other limestones and coals, and then by a considerable thickness of shales and bituminous limestones, in which we find not only the *Cythere*, but the scales of small fishes, bivalve shells (*Naiadites*)* allied to the common mussel, and a small whorled shell (*Spirorbis carbonarius*) resembling those now found adhering to the seaweeds of the shore (the common *Spirorbis spirillum*) Fig. 31. The bituminous limestones containing these remains, alternate with shales indicating that irruptions of mud partially filled up, at different times, the waters in which calcareous

* *Anthracomya* and *Anthracoptera* of Salter.

beds were being gradually accumulated by the growth and death of animals. In the highest of these beds of mud, which probably restored

Fig. 31.—*Fossils from Bituminous Limestone—Joggins.*



Cypris, (*a*) natural size. Spirorbis, (*a*) natural size. Naiadites.* Ganoid Scales.

the whole area to the state of a swamp, trees took root and were buried by an irruption of sand, in which they, as well as an undergrowth of *Calamites*, still stand in an erect position.

I have dwelt at some length on this subdivision, not that there is anything very remarkable in its structure, but that its appearances will help to explain others that succeed. It is evident that when read in the light of modern geology, they tell a very intelligible tale, and show us that the circumstances in which these coal-rocks were formed were similar to those which we have found to exist on a small scale in the modern marshes of the Bay of Fundy; and also to those more extensive changes which occur in the deltas of great rivers, such as the Mississippi and the Ganges, in which low alluvial flats have often been alternately covered with water and with a dense swamp-vegetation. Let the reader also observe, that in this group of the Joggins beds, we have at least five successive soil-surfaces, four of them sufficiently permanent to permit the accumulation on them of peaty vegetable soils; and about four feet nine inches of calcareous beds, mostly made up of animal remains. The lapse of time required for the accumulation of this group alone must thus have been vastly greater than that necessary for the production of the modern marsh formation with its one fossil soil. It will also be observed that these beds carry our thoughts back to a period when the district was covered by a strange and now extinct vegetation, and when its physical condition resembled that of the Great Dismal Swamp, the Everglades of Florida, or the Delta of the Mississippi.

One appearance only in this subdivision requires farther explanation before we proceed to the next. One of the sandstones in the upper part exhibits trees standing out from the cliff, as pillars of hard sand-

* For other figures and desriptions of these fossils, see notice at the end of this chapter.

stone spreading out at the base, and among these are numerous *Calamites*, also represented by sandstone casts, and, like the trees, standing at right angles to the beds, which are now inclined at an angle of 19 degrees, but which must have been horizontal when these plants grew and were entombed. The manner in which the plants were preserved in their present state and position can easily be understood. Imagine a forest of trees and a tall brake of reed-like plants growing together on a swampy flat. The flat is inundated and overspread with sand to the depth of several feet. The plants are thus killed and their dead tops project for some time above the sand. At length they decay and are broken off, and eventually the wood decays, leaving only a hollow cylinder of bark. Sand is next washed into the perpendicular pipes produced by the decay of the trunks and stems, forming casts of them. The whole is now buried up by succeeding deposits and becomes hardened into stone, and so remains until tilted up, elevated above the water level, and exposed by the action of the tides and waves.

One stump observed in the particular bed now under consideration is named in the section a *Lepidodendron*, with a note of interrogation to show that its surface was not so well preserved as to make it certain that it belonged to that genus. The *Lepidodendra* were tall and graceful trees, but allied botanically to the humble club-mosses (*Lycopodia*) of our modern woods. Their trunks were marked with diamond-shaped leaf-scars, and their branches and twigs were thickly clothed with long lance-shaped or linear leaves, and bore cones at their extremities. These trees did not send up straight trunks with numerous small branches, like the pines, but branched out by the continuous division of the trunk and limbs into pairs of branches, in the manner in which standard pear-trees are often trained by constantly cutting out the main ascending twig and allowing two lateral branches to grow in its place. The *Lepidodendra* must have been among the most beautiful trees of the coal period, and their roots would appear to have been constructed on the same regular type with those of the *Sigillaria*. Mr Brown of Sydney has described some trees believed to be *Lepidodendra*, and having such roots, in the coal-field of Cape Breton. Mr Carruthers, of the British Museum, has recently made a similar statement in regard to *Lepidodendra* in the British coal-fields. I have not, however, met with any instance of this in Nova Scotia.

Subdivision II. is a barren series of sandstones and shales, representing beds of sand and mud conveyed by water over the last terrestrial surface of the first group. For aught that the section shows to

the contrary, except in the occurrence of one underclay overlaid by coaly shale, these thirty-five feet of sand and mud may have been rapidly deposited. It is quite possible that the formation of the one inch of coal in the bottom of the group may have occupied a longer time than the deposition of the whole of the other beds. The reader will note here that the absolute thickness of any bed or mass of beds is no measure of the time occupied in their formation. A layer of sand may be spread over a wide surface by a single storm or inundation, but it requires time to accumulate even a very inconsiderable amount of organic matter by the slow growth of animals or plants.

The next Subdivision, No. III., including Coal-groups 40, 41, and 42, is very similar to No. I. It shows that the locality was again for a very long period alternately a swamp and a lagoon. I say for a very long time, for much of this group consists of bituminous limestone, *Naiadites* shales or "mussel beds," and coal, all beds requiring a very long lapse of time for their growth. There is every reason, for example, to believe that the three-feet bed of bituminous limestone, nearly in the middle of the group, consists mainly of the remains of *Cythere*, fish, and other aquatic creatures, accumulated by the slow growth of successive generations; and if we have any idea of the growth of modern beds of this kind, we will be disposed to measure the growth of this limestone by centuries.

Subdivision IV. is comparatively barren of organic remains, and consists of coarse mechanical detritus; and it will be observed that throughout the section groups of beds of this kind alternate with others composed of fine silt and organic matter. There were, in other words, long-continued swamp and lagoon periods, alternating with periods in which the waters of the sea or turbid streams were bearing in sand and mud. We have here, however, two surfaces which had sufficient permanence, as land or swamp soils, to support trees and *Calamites*.

In Subdivision V. we have a recurrence, on a small scale, of the conditions of Subdivision III.

Subdivision VI. is another great series of sandstones and chocolate-coloured shales. It has, however, one erect tree, probably a *Sigillaria*, rooted in an underclay with *Stigmaria* rootlets; and in the lowest sandstone there is a great mass of prostrate trunks of trees, imperfectly preserved, probably the wreck of some land-flood, or the drift-wood from a forest-clad coast.

In Subdivision VII. the beds present an order similar to that in the first group, and which we shall find frequently repeated in the section. First, we have an underclay, a soil on which grew a small

bed of vegetable matter represented by two inches of coal. This terrestrial surface was overflowed by water for a very long time inhabited by *Naiadites* and *Cythere*. This, it will be observed, implies subsidence of a terrestrial surface and its long submergence; and I may remark, once for all, that the appearances of the whole section imply continuous subsidence, only occasionally interrupted by elevatory movements. The bituminous limestone which marks this submergence is again succeeded by coal, again submerged under water inhabited by mollusks, *Cythere*, etc. The succeeding group marks the filling of the quiet waters tenanted by *Naiadites* with thick deposits of clay and sand, and in one little bed, about three inches in thickness, filled with the shells of the little land-snails known as *Pupa vetusta* and *Conulus priscus*, it shows evidence of neighbouring woods or swamps, from which some gentle stream must have drifted these little shells over the muddy bottom.

Subdivision IX. is a fine series of underclays and coals, alternating with mussel-beds. It contains seven distinct soil-surfaces, the highest* supporting an erect tree, which appears as a ribbed sandstone cast, five feet six inches high, nine inches in diameter at the top, and fifteen at the base, where the roots began to separate. This tree, being harder than the enclosing beds, at the time of one of my visits stood out boldly at the base of the cliff, nearly three-fourths of its diameter and the bases of three of its four main roots being exposed. Five of the underclays support coals, and in three instances bituminous limestones have been converted into soils, none of which, however, support coals. The last of these bituminous limestones is a very remarkable bed. First, we have an underclay; this was submerged, and *Spirorbis* attached its little shell to the decaying trunks, which finally fell prostrate, and formed a carbonaceous bottom, over which multitudes of little crustaceans (*Cythere*) swam and crept, and on which fourteen inches of calcareous and carbonaceous matter were gradually collected.

Then this bed of organic matter was elevated into a soil, and large trees, with *Stigmaria* roots, grew on its surface. These were buried under thick beds of clay and sand, and it is in the latter that the erect tree already mentioned occurs; its roots, however, are about nine feet above the surface of the limestone, and belong to a later and higher terrestrial surface, which cannot be distinguished from the clay of similar character above and below.

The Xth Subdivision contains a vast thickness of sandstone and shales, the latter chiefly of chocolate colours. It shows comparatively meagre indications of the swamp-deposits previously in progress.

* Included in the lower part of Subdivision X. of the section.

During the greater part of the time occupied in the formation of these beds, the locality must have been a sandy or muddy sea-bottom, receiving much mechanical detritus, or an expanse of flats of reddish mud and brown or gray sand, covered by the tides. There are, however, some evidences of terrestrial conditions. In the lowest beds is a large erect stump, filled with laminated clay after the complete decay of its wood. In the clay filling it were abundance of fern leaves, *Cordaites*, *Lepidophylla*, a few plants with attached *Spirorbis*, and a shell of *Naiadites*. This tree was rooted in a thick underclay full of rootlets of *Stigmaria*. Higher up there are several thin coaly bands, with underclays; many of the shales abound in leaves of Ferns and *Cordaites*, probably drifted, and the highest sandstone showed a large erect tree.

Subdivision XI. commences with a soil resting immediately on the truncated top of the tree last mentioned. On this soil was formed a deep swamp, now represented by three feet of coal and bituminous shale in alternate bands. Large quantities of clay and sand buried this swamp, but not in such a manner as to preclude the growth of trees, many of which were entombed in the erect position. In these sandstones and shales, no less than six erect trees were observed at different levels, the lowest being rooted in the shale forming the coal-roof; fifteen feet of the trunk of one of these trees still remain; two others were respectively five and six feet high. Erect *Calamites* were also observed. The soil which was formed on the surface of these beds supports one of the thickest coal-beds in the section, marking a long and undisturbed accumulation of vegetable matter; and after the deposition of 18 feet of underclay and shales, there is another equally thick though coarser bed. We have here, as in some previous groups, three distinct conditions of the surface:—first, terrestrial surfaces more or less permanent; secondly, undisturbed marine or brackish water conditions; thirdly, intervening between these the deposition, probably with considerable rapidity, of sandy and muddy sediment. We may also observe that, admitting the *Stigmaria* to be roots of trees, there are five distinct forest soils without any remains of the trees, except their roots; and we shall find throughout the section that the forest soils are much more frequently preserved than the forests themselves.

In the large series of beds included in Subdivisions XII. and XIII., there are no less than thirteen distinct forest surfaces marked by underclays or erect trees, and at least five periods of submergence indicated by mussel-beds, and three of them, at least, of very long duration. It will be observed that, in several instances, the order of

succession is underclay—coal—bituminous limestone. This arrangement, so common in other parts of the section, seems to show a connexion other than accidental between the long periods of terrestrial repose required for the growth of coal, and those of quiet submergence necessary for the growth of mussel-beds. Probably the peaty areas of coal accumulation were gradually subsiding, and when this process finally caused their submergence, the submerged coal-swamp was the most fitting habitat for *Naiadites* and its associates; and these sunken swamp areas may have been so protected by thick margins of jungle as to resist for a long time the influx of turbid waters.

In the lower part of No. XIII., and immediately above Coal-group 21, I observed a very curious association of erect plants. An erect tree, converted into coal, springs from the surface of the shale, and passes through fourteen feet of sandstone and shale. Apparently from the same level there rises an erect ribbed tree, probably a *Sigillaria*, in the state of a stony cast, which, however, extends only to the top of the sandstone. In the sandstone, and rooted about a foot above the base of the erect trees, are a number of erect *Calamites*. In this case the forest soil has been covered by about a foot of argillaceous sand, on which a brake of *Calamites* sprung up. Further accumulations of sand buried them, and covered the trunks of the trees to the depth of eight feet. By this time the *Sigillaria* was quite decayed, and its bark became a hollow cylinder, reaching only to the surface of the sand, and ultimately filled with it. The other tree still stood above the surface until six feet of mud were deposited, when, its top being broken off, it also completely disappeared beneath the accumulating sediment; and being softened and crushed by the lateral pressure of the surrounding mass, it was finally converted into an irregular coaly pillar, retaining no distinct traces either of the external form or internal structure of the original plant. The structure of similar trees, to be noticed further on, renders it likely that this coaly tree is the remains of one of the *Araucarian Pines*, which, it appears, flourished in the coal-swamps in company with the *Sigillariæ*. The surface of the clay which buried this remarkable tree became itself an underclay or soil; and on the sandstone resting upon it were found casts of two erect trees, one of them five feet in height, and a *Sigillaria* with distinctly marked leaf-scars. The tops of these trees have been entirely removed, and their hollow stems filled with sand, before the deposition of a bed of mud resting upon them, and which is now the underclay of a bed of coal. This coal was next submerged under the conditions required for bituminous limestone and mussel-beds. The

During the greater part of the time occupied in the formation of the beds, the locality must have been a sandy or muddy sea-botton receiving much mechanical detritus, or an expanse of flats of reddis mud and brown or gray sand, covered by the tides. There are, how ever, some evidences of terrestrial conditions. In the lowest beds a large erect stump, filled with laminated clay after the complete deca of its wood. In the clay filling it were abundance of fern leave *Cordaites*, *Lepidophylla*, a few plants with attached *Spirorbis*, and shell of *Naiadites*. This tree was rooted in a thick underclay full rootlets of *Stigmaria*. Higher up there are several thin coaly band with underclays; many of the shales abound in leaves of Ferns an *Cordaites*, probably drifted, and the highest sandstone showed a larg erect tree.

Subdivision XI. commences with a soil resting immediately on th truncated top of the tree last mentioned. On this soil was formed deep swamp, now represented by three feet of coal and bituminou shale in alternate bands. Large quantities of clay and sand burie this swamp, but not in such a manner as to preclude the growth trees, many of which were entombed in the erect position. In the sandstones and shales, no less than six erect trees were observed different levels, the lowest being rooted in the shale forming the co roof; fifteen feet of the trunk of one of these trees still remain; t others were respectively five and six feet high. Erect *Calamites* w also observed. The soil which was formed on the surface of th beds supports one of the thickest coal-beds in the section, markir long and undisturbed accumulation of vegetable matter; and after deposition of 18 feet of underclay and shales, there is another eq thick though coarser bed. We have here, as in some previous gr three distinct conditions of the surface:—first, terrestrial su more or less permanent; secondly, undisturbed marine or br water conditions; thirdly, intervening between these the depo probably with considerable rapidity, of sandy and muddy sed We may also observe that, admitting the *Stigmaria* to be r trees, there are five distinct forest soils without any remains trees, except their roots; and we shall find throughout the that the forest soils are much more frequently preserved t forests themselves.

In the large series of beds included in Subdivisions XII. an there are no less than thirteen distinct forest surfaces m underclays or erect trees, and at least five periods of sub indicated by mussel-beds, and three of them, at least, of duration. It will be observed that, in several instanc

succession is underclay—coal—bituminous limestone. This arrangement, so common in other parts of the section, seems to show a connexion other than accidental between the long periods of terrestrial repose required for the growth of coal, and those of quiet submergence necessary for the growth of mussel-beds. Probably the peaty areas of coal accumulation were gradually subsiding, and when this process finally caused their submergence, the submerged coal-swamp was the most fitting habitat for *Naiadites* and its associates; and these sunken swamp areas may have been so protected by thick margins of jungle as to resist for a long time the influx of turbid waters.

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quiet waters were then filled up with clay and sand, the latter ripple-marked, and with drifted vegetable fragments. Another soil was formed above these beds, and on it we find an inch of coal, with flattened *Sigillariæ*, which probably once grew on the underclay. This terrestrial surface was succeeded, as usual, by waters swarming with *Naiadites* and fish, and on these were spread out beds of sand and mud, with ripple-marks, drift trees, and evidences of partial denudation by currents. A terrestrial surface was again restored, and four inches of coal were accumulated; but the waters again prevailed, and in the coal itself we find *Naiadites*, *Cythere*, and plants covered with *Spirorbis*, indicating that these creatures took possession while the vegetable matter was still recent, and probably much of it in an erect position. A terrestrial surface was, however, soon restored; for in the shale which covers the coal there is a fine ribbed stump, two feet in diameter, and displaying on its roots the markings of the true *Stigmaria ficoides*, as well as the rootlets *in situ* in the shale. This is the first instance we have here yet met with of the distinct connexion of an erect ribbed stem with its Stigmaria roots. The causes of the difficulty of observing the roots and stem in connexion will be stated in the sequel.

The next Subdivision is in great part the result of somewhat rapid mechanical deposition. It contains thick beds of sandstone, deposited by currents which have undermined wooded banks, or passed through recently submerged forests, for they contain numbers of trunks of different trees, retaining their bark and surface markings. Its coals are few and insignificant. There are, however, erect trees and *Calamites* at three levels; and one of the trees springs from a shade loaded with *Cordaites* which may have grown around its base.

Here we may pause for a little, to note the appearance of some of the new vegetable remains to which we have been introduced. We have found a *Sigillaria* with distinct markings, namely, its sides marked with bold ribs, having the effect of the flutings of a Grecian column, and these ribs dotted with vertical rows of leaf-scars. We have also seen a distinct instance of a *Sigillaria* attached to its Stigmaria roots still spreading through the soil. (See Fig. 30, page 180.) Let us now endeavour to form an idea of the trees of this singular genus. Imagine a tall branchless or sparsely branching trunk, perhaps two feet in diameter, and thirty feet in height. (One has been traced to the length of forty feet in the roof of the Joggins main coal-seam.) The trunk is covered with a thick bark, very smooth, and ribbed regularly, and is clothed to the summit with a dense mass of leaves, probably of lengthened and grass-like forms. Such trees must have

formed dense groves in the swamps of the Coal period. They have nothing closely analogous to them among living plants. There were a number of species of *Sigillaria*, differing somewhat in their ribs and leaf-scars, and probably also in their leaves. *Lepidophloios* or *Ulodendron*, a plant whose remains occur with the *Sigillaria*, was allied to the *Lepidodendron*, but wanted its slender graceful branches, while it had rows of stiff cones planted on the sides of its trunk: and its general aspect, when clothed with its long leaves, somewhat broader than those of *Lepidodendron*, must have much resembled that of the *Sigillaria*. *Lepidophylla* were the leaves of *Ulodendron* or *Lepidodendron*.

We have also met with the *Cordaites*, long striated leaves resembling those of gigantic plants of Iris or Indian corn, and sometimes five or six inches in breadth, and half as many feet in length. They grew on thick stems under and around the sigillarian woods though sometimes probably covering great tracts without any admixture of other plants. We have also observed an erect coniferous tree, and erect *Calamites*, but shall reserve our notice of these for better instances farther on. Lastly, fronds of Ferns appear in some of the beds; and I may state here that they are much less abundant relatively to the other plants at the Joggins than elsewhere in the Coal-fields of Nova Scotia and Cape Breton.

Subdivision XV. is one of the most interesting in the section, in consequence of the discovery in it, in 1852, by Sir Charles Lyell and the writer, of the bones of a reptile, *Dendrerpeton Acadianum* (Fig. 32), those of another small reptile, and the shell of a land snail (*Pupa*

Fig. 32.—*Jaw of Dendrerpeton Acadianum.*

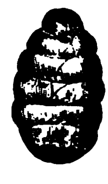
(*a*) Cross section of Tooth (magnified).

vetusta) (Fig. 33).* These remains are of great interest, as they were the first reptilian animals found fossil in the Carboniferous rocks of America, and the only land snail whose remains had ever been found in rocks of that age; in fact, the first evidence obtained of the

* The figures given here represent two of the original specimens found in 1852. Better specimens are figured further on.

existence of animals of that tribe at so early a period. These interesting remains were all found in the interior of an erect tree, mingled

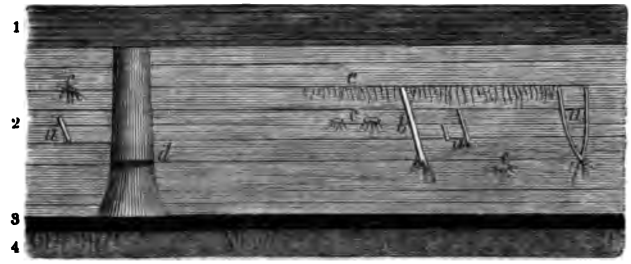
Fig. 33.—*Fossil Land Shell—Joggins Coal Measures.*



Magnified three diameters.

with the sand, decaying wood, and fragments of plants which had fallen into it after it became hollow. The bed of argillaceous sandstone, nine feet in thickness, which enclosed this tree, contains a number of erect plants (Fig. 34). Three erect trees in the form of sandstone casts and erect *Calamites* were observed in it, with many Stigmaria roots. There was also a tree not in the form of a cast, but of a mass of coaly fragments surrounded by a broken and partly crushed cylinder of bark; the whole being evidently the remains of a trunk which has been reduced to little more than a pile of decayed

Fig. 34.—*Section of middle part of Subdivision XV. in which the Dendrerpeton, Land Shells, etc., have been found.*



1. Underclay, with rootlets of *Stigmaria*, resting on gray shale, with two thin coaly seams.
2. Gray sandstone, with erect trees, *Calamites*, and other stems: 9 feet.
3. Coal, with erect tree on its surface: 6 inches.
4. Underclay, with Stigmaria rootlets.

(*a*) *Calamites.* (*c*) Stigmaria roots.
(*b*) Stem of plant undetermined. (*d*) Erect trunk, 9 feet high.

pieces of wood before the sand was deposited; consequently it must have been either an older or more perishable plant than those which stand as pillars of sandstone. The wood of this tree shows, in the cross section, a cellular tissue, precisely similar to that of the Coniferæ;

the longitudinal section shows only elongated cells, but is very badly preserved. A tree of this description is not likely to have been more perishable than the *Sigillariæ*, which, in the same situation, remained until nine feet of sandy mud had accumulated. I suspect, therefore, that this stump may be the remains of a Coniferous forest, which preceded the *Sigillariæ* in this locality, and of which only decaying stumps remained at the time when the latter were buried by sediment. This is the more likely, as the appearances indicate that this tree was in a complete state of decay at the very commencement of the sandy deposit. It is, however, possible that this older forest, represented by coaly stumps, may have consisted of Sigillaroid trees.

The history of this group will thus be as follows:—(1.) The Stigmaria underclay shows the existence of a Sigillaria forest, on the soil of which was collected sufficient vegetable matter to form six inches of coal, which probably represents a peaty bog several feet in thickness. (2.) On this peaty soil grew the trees represented by the stump of mineral charcoal mentioned above. This tree, being about one foot in diameter, may have required about fifty years for its growth to that size. It was then killed, perhaps by the inundation of the bog. (3.) During the decay of the tree last mentioned, *Sigillariæ* grew around it to the diameter of two feet, when they were overwhelmed by sediment, which buried their roots to the depth of about eighteen inches. At this level *Calamites* and other *Sigillariæ* began to grow, the former attaining a diameter of four inches, the latter a diameter of about one foot. (4.) These plants were in their turn embedded in somewhat coarser sediment, but so gradually that trees with stigmarian roots grew at two higher levels before the accumulation of mud and sand attained the depth of nine feet, at which depth the original large *Sigillariæ* that had grown immediately over the coal were broken off, and their hollow trunks filled with sand. Before being filled with sand, these trees, while hollow, must for some time have projected from a swamp or terrestrial surface, such as that which immediately succeeds them in ascending order; and it is no doubt to this circumstance that we owe the occurrence, in some of them, of reptilian remains and land shells, as well as many vegetable fragments, such as *Calamites*, *Cordaites*, and a *Lepidostrobus*, with many of the fossil fruits called *Trigonocarpa*, evidently introduced before the sedimentary matter, and forming just such a mass as might be supposed likely to fall into an open hole in a forest or swamp. (5.) The remaining beds of this group evidence the continuation of swamp conditions for a long time after the trees last noticed were completely buried. They include, in a thickness of twenty-eight feet, three underclays supporting

coaly beds, and one with erect stumps; one of them with stigmarian roots and ribbed. One of the coaly beds, which alternates with laminæ of shale, is filled with flattened trunks of *Sigillaria* and *Lepidodendron*, which probably grew on the surfaces on which they now lie, and indicate how small a thickness of coaly matter may mark the time required for the growth and decay of many successive forests.

On the whole, we can scarcely err in affirming that the habitat of the *Dendrerpeton Acadianum* and its associates was a peaty and muddy swamp, occasionally or periodically inundated, and in which growing trees and Calamite brakes were being gradually buried in sediment, while others were taking root at higher levels, just as now happens in the alluvial flats of large rivers. In subsequent visits to this interesting locality, I found the remains of four other species of reptiles or batrachians, an ancient representative of the gally-worms (*Xylobius Sigillariæ*), and remains of an insect. These will be de-

Fig. 35.—*Erect Tree containing Reptilian Remains, at the Joggins.*

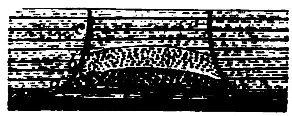
scribed further on. In Figs. 35 and 36 I give a representation of one of the trees, and a section showing the arrangement of the materials filling the base.

Subdivision XVI. consists of one thick bed of gray sandstone with prostrate carbonized trunks. The sandstone is highly silicious, and of the kind used for grindstones. It is the result of the complete

submergence of the swamps of the last group, and their invasion by sand-bearing currents.

The next Subdivision commences with the growth of *Calamites* on the surface of the great sand-bed last noticed, after which there was the formation of an underclay and coal, the latter being afterwards inundated, and the plants at its surface overgrown with *Spirorbis*. In the shale covering this coal, about fourteen feet above its surface, is a bed with shrinkage cracks, and containing a stool of *Stigmaria*, one of the roots of which was traced 9½ feet. Its rootlets were attached, so that it can scarcely have been a drift stump; and if now *in situ*, it must have grown on a mud-bank alternately inundated and dry, like the present salt-marshes of the Bay of Fundy.

Fig. 36.—*Section of Base of Erect Sigillaria.*



(*a*) Mineral charcoal. (*b*) Dark-coloured sandstone, with plants, bones, etc.
(*c*) Gray sandstones with *Calamites* and *Cordaites*.

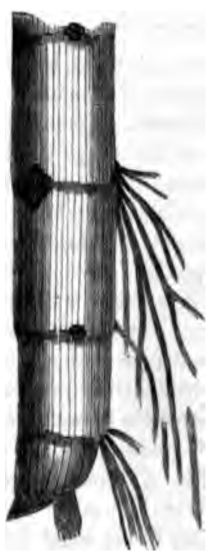
Subdivision XVIII. is a series of sandstones and shales, less perfectly exposed than most other parts of the section. Chocolate colours prevail among the shales, and there are few fossils. One of the beds, however, has its surface covered with casts of shrinkage cracks, such as are now formed on mud left dry by the neap tides; and there are also erect *Calamites* in one bed and a Stigmarian underclay.

The next group is of much greater interest, showing seven soil-surfaces, with a variety of sedimentary deposits. Two of the coals in this group contain on their surfaces of deposition well-preserved remains of the plants (*Sigillaria*, *Cordaites*, *etc.*) which must have grown on their underclays. A thick mass of sandstone and shale in the centre of the group is also very curious, as it evidently represents the side of a trench or gully cut by water in a series of mud-beds, and then filled up with a confused mass of drift trees and sand. Above this mass is an underclay, on which grew a forest, whose only remains are a few inches of coaly matter (Gr. 11), made up in part of flattened trunks converted into coal. This forest must have been entirely destroyed by violence or decay, before the next bed, which is a shale seven feet thick, was deposited. On the surface of this shale grew a great brake of *Calamites*, which were buried under sand, in such a manner that their forms and position were perfectly preserved: they stand in groups in the cliff just as they grew, some of them being five inches in diameter, and eight feet high; and at that height they

have been broken off without any decrease of their diameter. In one place twelve stems were counted in eight feet measured along the face of the cliff. From the base of the cliff to low-water mark, they could everywhere be seen abundantly along the continuation of the ledge of sandstone. This bed and others of similar character at the Joggins, have given us much information respecting the nature and mode of growth of these plants, which I may pause here to notice in detail.

The *Calamites* were tall cylindrical stems, with a hard outer bark, and were either hollow or filled with cellular matter. The stems were regularly marked with longitudinal striæ or furrows and cross joints, sometimes showing the marks of the attachment of the leaves, which were verticillate, or in whorls around the stem, and long and needle-like (Figs. 37 and 38). The general habit of growth thus

Fig. 37.—*Erect Calamites* (*C. Voltzii*), *with Roots.*



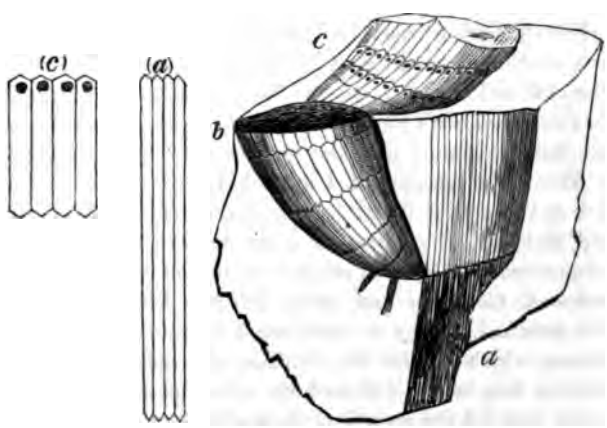
One-sixth natural size.

Fig. 38.—*Leaves of Calamites* (*C. Cistii*)

resembled the *Equisetum* or Mare's-tail of modern marshes, and probably these plants are also allied to the *Calamites* in structure. *Cala-*

mites grew on wet mud and sand-flats, and also in swamps; and they appear to have been especially adapted to take root in and clothe and mat together soft sludgy material recently deposited or in process of deposition. When the seed or spore of a Calamite had taken root (and it is not unlikely that, like the very remarkable spores of the *Equiseta*, their seeds had wings which expanded to waft them through the air when dry, and closed instantly when they touched the damp soil), it probably produced a little low whorl of leaves surrounding one small joint, from which another and another, widening in size, arose, producing a cylindrical stem, tapering to a point at the base. To strengthen the unstable base, the lower joints, especially if the mud had been accumulating around the plant, shot out long roots instead of leaves, while secondary stems grew out of the sides at the surface of the soil, and in time there was a stool of *Calamites*, with tufts of long roots stretching downwards, like an immense brush, into the mud (Fig. 37. See also Fig. 39). When *Calamites* thus grew

Fig. 39.—*Erect Calamites* (*C. Suckovii*), *showing the Mode of Growth of New Stems, and Forms of the Ribs.*



Natural size. Half natural size.

(*a*) Old stem. (*b*) Second stem, budding from first. (*c*) Third stem, budding from second.

on inundated flats, they would, by causing the water to stagnate, promote the elevation of the surface by new deposits, so that their stems gradually became buried; but this only favoured their growth, for they continually pushed out new stems, while the old buried ones shot out bunches of roots instead of regular whorls of leaves. These peculiarities have caused much dispute among botanists, some of whom have even fancied that the whole stem served as a root. All the

apparent anomalies were, however, wise contrivances to fit the plant for its office in nature.

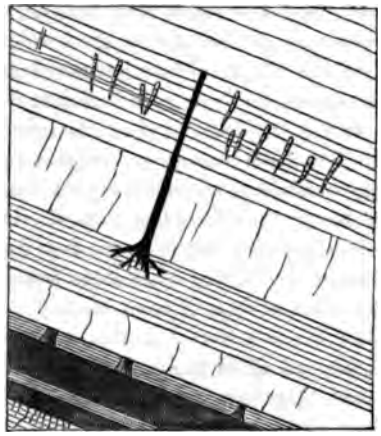
One peculiarity in these beds well illustrates the fact already mentioned, that the thickness of beds is no certain criterion of the time occupied in their formation. The bed of sandstone, eight feet in thickness, enveloping the *Calamites*, must have been deposited in a few years at most. The underlying coal is all that marks the growth, submergence, and decay of a forest.

Subdivision XXIII. is a great and continuous series of swamp and estuary deposits, including the most important bed of coal in the section, and a large number of well-marked terrestrial surfaces. It commences with a black bituminous underclay, a soil probably of long continuance, and filled with rootlets. This supports a foot of coal known to the miners as the "Queen's Vein" (Coal-group 8), above which we find three other coals with underclays, and one of them with a shale roof full of prostrate plants. Then we have an underclay capped by shale with fossil leaves, but no coal. Above this we have an interruption of the previous conditions, by the deposition of sand, on the surfaces of which drift-plants were scattered, and became tenanted by the little worms whose shells we have referred to *Spirorbis*. On these sandstones Stigmaria again took root, and one bed is filled, from the cliff to low-water mark, with well-preserved stools of these singular roots, each with four main divisions, branching dichotomously. A single inch of impure coal was the result of this dense growth of trees. Above this accumulated a thick boggy underclay, on which a varied and beautiful forest has grown, which was overturned or uprooted, and now lies prostrate in a thin band of ironstone and shale. In the ironstone of this band are four species of *Sigillaria*, and great multitudes of *Cordaites* and other leaves. All these fossils had *Spirorbis* attached. They no doubt mark the site of a submerged and fallen forest, which but for the abundant deposition of fine mud and carbonate of iron, which followed its submergence after an interval sufficiently long for the growth of *Spirorbis*, would have appeared as a thin coaly layer. Above this, after an interval occupied by shales and sandstone with one thin coal, we find a thin coaly layer almost entirely composed of *Cordaites*. No roots appear in the underlying shale, and we may therefore doubt whether these leaves grew *in situ*, or were scattered over the bottom of water. On this coal is a thick clay supporting, some years ago, two erect stumps. From the clay in which they were rooted they passed upward, through a sandstone two feet in thickness, into a shale with ironstone bands above. The smaller stump was fluted, but without leaf-scars. Its roots were

concealed under the beach. It was filled with sandstone to the height of seven inches above the level of the sandstone without, indicating that this bed must have suffered from denudation, after having contributed materials toward the filling of the stump. It is probable that the sand within the bark was originally lower than that without. If so, the sandstone may have lost much more than seven inches; and of this, but for the presence of this stump, there would have been no evidence. The neighbouring tree, though rooted at the same level, was brought by the dip of the beds to a sufficient height to allow its roots to be seen. It was originally of the same height with the other, but the upper part had been removed. In this stump we see that while the sandstone within has extended higher than that without, it has also descended lower, though not quite to the bottom, this being filled with clay. We thus find that after the tree became hollow, and while its top continued to stand at least three feet above the surface, it was partly filled with a deposit from muddy water. The mud within was, however, much lower than that without when the sand began to be deposited, and filled the greater part of the stump. The roots of this tree had Stigmaria markings, and the rootlets could be seen penetrating the shale beneath. Portions of the surface of the trunk showed the markings of a broad-ribbed *Sigillaria*, with oval leaf-scars on the ligneous surface. The roots descend somewhat rapidly into the clay, and perhaps even reach the coaly layer below. The overlying shales bend downward into the upper part of these stumps, indicating that the material within was more compressible than that without. Perhaps this is due to the compression of woody matter remaining in the bottom of the cavity left by the decay of the trunk. The circumstances in which these stumps were preserved strikingly illustrate the strength and durability of the bark of *Sigillaria*. Above this bed there are about thirty feet of shales, with ironstone bands and sandstones, including a few thin layers of coal, and apparently several underclays; but the coal railway and pier prevent them from being well seen. On these rests the main coal or "King's Vein" (Coal-group 7). The main coal and a layer of clay six inches thick overlying it, have supported a forest of *Sigillariæ*, some of which remain as erect stumps, others are prostrate. Very fine speçimens have been extracted from this bed in working the coal. Their surfaces are often covered with *Spirorbis*. This forest was buried under eight feet of sand and clay; and from the surface of the latter sprang an erect tree, which was observed to extend upward to the height of fifteen feet, and was then abruptly broken off. The rocks enclosing it are sandstone and arenaceous shale. (Fig. 40.) This tree, like one

previously mentioned, was a pillar of coaly matter, without distinct external markings, and compressed by lateral pressure. Its preservation in this manner shows that it was composed of durable wood, but

Fig. 40.—*Beds overlying Joggins Main Coal, with erect Tree and Calamites.*



1. Shale and sandstone. Plants with Spirorbis attached; Rain-marks (?)
2. Sandstone and shale, 8 feet. Erect Calamites.
3. Gray sandstone, 7 feet.
4. Gray shale, 4 feet.
5. Gray sandstone, 4 feet.

{ An erect coniferous (?) tree, rooted on the shale, passes up through 15 feet of the sandstones and shale.

6. Gray shale, 6 inches. Prostrate and erect trees, with rootlets; leaves; *Naiadites;* and *Spirorbis* on the plants.
7. Main coal-seam, 5 feet coal in two seams.
8. Underclay, with rootlets.

by no means proves that it differed from those trees which are found in the state of stony casts. An erect tree, the wood of which had time to decay before it was buried by detritus, would appear as a cast in sand or clay. The same tree, if broken off and buried before the decay of its wood, might appear as a pillar of coal. This tree is, however, proved, by portions of its wood which retain their structure, to have been coniferous.

After deposits of sand had extended to the height of at least ten feet above the root of this tree, and while its top projected above the surface, *Calamites* grew around, attaining a diameter of $1\frac{3}{4}$ inch, and a height of at least five feet. They are very numerous, and though perhaps a different species from those in the great calamite bed before mentioned, grew in the same manner. They were buried by five feet of sand and arenaceous mud, after which their tops and that of the

erect tree were removed or decayed, and the sands next succeeding contain only drift vegetable fragments, having *Spirorbis* attached to them. Above these is an inch of coal, loaded with *Cordaites*, and it is to be observed that this is the second instance of thin coals of this kind without Stigmaria underclays. Immediately above this is a sandy soil with Stigmaria and rootlets, but without coal or erect trees. Shales and sandstones succeed; and above these we have a very thick underclay full of rootlets. This soil, after the growth upon it of coaly matter, and a forest or successive forests of *Sigillaria*, was submerged in such circumstances that scarcely any mechanical detritus was deposited upon it. The trees remained erect in the bottom of clear waters, inhabited by fishes and *Cythere*, until *Spirorbis* attached itself to their trunks. They at length fell and sank to the bottom; and, with the vegetable soil, form a bed of impure coal four inches in thickness, and abounding in scales of fishes and trunks covered with *Spirorbis*. Long after the forest disappeared, these aquatic conditions continued, and ten inches of calcareo-bituminous shale with *Naiadites*, fish-scales, and *Cythere* were deposited, as usual passing upward into barren gray shale. This is a fine instance of an order of succession which we had frequent occasion to notice in the earlier part of the section.

In the next Subdivision the waters retain their dominion, though probably diminishing in depth, in consequence of the deposition of detrital matter. The sandstones of this group are very uniform and evenly bedded, as compared with those in the last, and present no indications of vicinity to shores or water-courses, except in the presence of drift-wood, and of singular scratches and furrows on the surfaces of the shales, fine casts of which have been taken by the overlying sand. Scratches and marks of this kind are very frequent in the Coal Formation. They occur on a grand scale in the Pictou freestone quarries, and are also very abundant near Tatamagouche. Many of them might very easily be included in the convenient tribe of *Fucoides*, that is, remains of sea-weeds, but their want of uniformity in everything except direction, their want of organic matter, and occurrence in beds containing drift-wood, make it most probable that they were scratches produced by the roots and branches of trees borne over the surface by currents of water, and similar to those which may be seen on the inundated mud-flats of wooded countries. Such marks are usually straight, like diluvial striæ, but when stumps or tree-tops ground and are borne off, the most fantastic markings are produced, partly by the eddying of the current around the obstacles opposed to it.

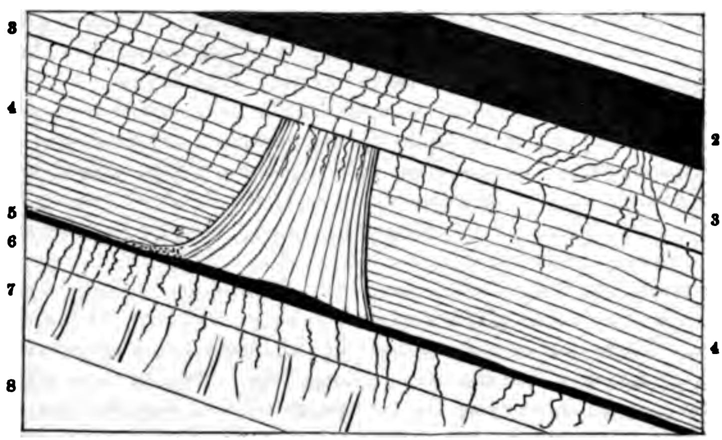
In Subdivision XXV. we have a dense series of fossil soils, with thin coaly layers. It terminates upwards in bituminous limestone, with its

usual fossils and resting on coal. This is a case precisely similar to that which terminates our 23d group, except that in this last case the conditions favourable to the formation of bituminous limestone probably continued longer.

The next is another barren group of chocolate and gray shales, with gray sandstone occasionally rippled, and with fragments of drift-wood. This is the filling up of the shell-fish-inhabited waters, in the manner already so frequently noticed. In one of its beds I observed rain-marks, and a series of footprints, probably of a small reptile; and it was here that Mr Marsh found the vertebræ of the largest reptile yet discovered at the Joggins, *Eosaurus Acadianus*.

Subdivision XXVII. is another succession of underclays and small coaly layers. It is remarkable for the very pyritous character of many of its beds, an indication of the action of sea-water. The most remarkable part of this group is that represented in Fig. 41. It

Fig. 41.—*Section from the lower part of Subdivision XXVII.*



1. Shale. 2. Shaly coal, 1 foot. 3. Underclay with rootlets, 1 foot 2 inches. 4. Gray sandstone passing downwards into shale, 3 feet. Erect tree with Stigmaria roots (*e*) on the coal. 5. Coal, 1 inch. 6. Underclay with roots, 10 inches. 7. Gray sandstone, 1 foot 5 inches. Stigmaria rootlets continued from the bed above; erect *Calamites*. 8. Gray shale, with pyrites. Flattened plants.

includes a bed of erect *Calamites* and an erect tree with distinct Stigmaria roots. The underclays are here so crowded on the erect plants, that the rootlets of one underclay pass downward among the erect *Calamites*, and the rootlets of another pass beside and within the cast of the erect tree, the surface markings of which they have helped to

obliterate by passing downward immediately within the bark. The calamites are rooted in shale, and the erect tree in an ordinary underclay, supporting a thin layer of coal which rises a little immediately under the stump, being there either protected from pressure or increased by the addition of woody matter derived from the trunk. This stump, it will be observed, expands rapidly towards its base. This group terminates upward in a mussel-bed resting on coal.

The whole series of events in the preceding historical sketch has depended on the following conditions:—Gradual and long-continued subsidence, with occasional elevatory movements, going on in an extensive alluvial tract teeming with vegetable life and receiving large supplies of fine detrital matter. On the one hand, subsidence tended to restore the original dominion of the waters. On the other hand, elevation, silting up, and vegetable and animal growth built up successive surfaces of dry land. For a very long period these opposing forces were alternately victorious, without effecting any very decided or permanent conquest; and it is very probable that the locality of our section was, during this period, near the margin of the alluvial tract in question, where the various changes of the conflict were more sensibly felt and more easily recorded than nearer the open sea or farther inland.

The portion of the section above described in detail includes a thickness of 2819 feet of the central part of the Coal formation, constituting Division 4 of Logan's section.

It is impossible to contemplate this vast series of deposits without being forcibly impressed with the great lapse of time and variety of change which it indicates; and a glance at the table of formations in the introduction to this work, will show how small a portion of the whole geological history of the earth is represented by the coal measures. It is to be borne in mind also that this section represents the structure of the whole plain of Cumberland, and in a less precise manner that of the whole Carboniferous areas of Nova Scotia and New Brunswick, with great tracts composed of similar rocks, but not elevated above the bed of the present seas. I do not wish it to be understood, however, that all the changes represented by the Joggins beds extended continuously over large areas. On the contrary, I believe that had we visited Cumberland during the Coal period, we might, by changing our position a few miles, have passed from a sandy shore to a peaty swamp, or to the margin of an estuary or lagoon; but I believe that in each locality these changes succeeded each other in a similar manner, and that the great alternations between terrestrial growth and marine deposition extended over very wide areas. Had

we visited Cumberland during the time represented by one of the groups of coals, bituminous limestones, and erect forests, we should have beheld vast swampy plains covered with dense forests, calamite brakes, and peaty bogs, intersected by sluggish streams and shallow lagoons. Had we visited it perhaps some centuries later, at the time when one of the barren groups of sandstone was being deposited, the eye would have ranged over a wide and shallow sea, filled with sand-banks, and with occasional low islets and spits, covered with Sigillariæ and fringed with wide borders of Calamites, struggling for existence among the shifting sands. Changes of this kind alternated again and again, while the whole area was constantly subsiding at a rate so slow, that mechanical deposition and animal and vegetable growth were able to a great extent to counteract and sometimes altogether to neutralize its influence. At length, however, in the Upper Coal formation, aqueous conditions regained a decided preponderance. This, then, be it borne in mind, was the process employed by the great Architect of the universe in building up the Coal-fields of Nova Scotia and of the world; and we are indebted to the clean and sharp section effected by the tides of Chiegnecto Bay for that fine exposure of its stony monuments which enable us to understand and explain in such detail its nature.

Remains of Aquatic Animals in the Coal Measures.

I propose in the sequel to devote an entire chapter to the *land* animals of the Coal formation. In the present note, I desire to state some interesting facts in regard to the remains of *aquatic* animals which abound in the shales and bituminous limestones, associated with plants, and without any intermixture of brachiopods, corals, or other absolutely marine productions. Though I do not consider these creatures as fresh-water animals, yet they must be regarded as the tenants of brackish, and perhaps sometimes fresh, ponds, lagoons, and creeks of the Coal formation swamps, and which must have been, for the most part, shallow, land-locked, and filled with putrid vegetable matter, though no doubt often at the sea level, and communicating with it by channels more or less wide.

I. *Bivalve Shells.*—All the Lamellibranchiate shells, which are so numerous in some of the shales and bituminous limestones of the Joggins that some of the beds may be regarded as composed of them, belong to one generic or family group. They are the so-called Modiolas, Unios, or Anodons of authors. I proposed for them, some years ago, the generic name of *Naiadites*, and described six species from the Coal measures of Nova Scotia, stating my belief that they

are allied to *Unionidæ*, and that their nearest analogue may be the genus *Bysso-anodonta* of D'Orbigny, found in the River Parana.* Mr Salter, however, to whom I sent specimens, regards these shells as belonging to his new genera *Anthracomya* and *Anthracoptera*, the former being supposed to be allied to *Myadæ*.† More recently Gümbel and Geinitz have described similar shells from Thuringia as belonging to the genera *Unio* and *Anodon*, and regard my *Naiadites carbonarius* (*Anthracoptera carbonaria* of Salter) as a *Dreissena*.‡ In the present uncertainty as to their genuine relations, I shall retain the name *Naiadites* for the whole of the species, giving, however, Salter's generic names in brackets. The genus *Anthracosia* of King, which is evidently distinct from *Naiadites*, has been recognised in Nova Scotia only in the Lower Coal formation of Baddeck, C. B. A specimen found at that place by Mr Barnes will be noticed in the sequel. As these shells swarmed in the waters of the Coal formation estuaries or lagoons, facts tending to the elucidation of their habits and affinities are important with reference to the coal; I would therefore make the following remarks in relation to them:—

(1.) Under the microscope, the shells of the thicker species, as *Naiadites carbonarius*, present an internal lamellar and subnacreous layer, a thin layer of vertical prismatic shell, and an epidermis—these structures being entirely similar to those of *Unionidæ*. In the thinner species, as in *N. lævis*, only the prismatic coat appears, and in this the prisms are in some instances placed obliquely. These thin shells, however, show evidence of an epidermis. (2.) The ligament was external, there seem to have been no teeth, the shell was closed posteriorly; but there are indications of a byssal sinus. Mr Salter describes the epidermis as wrinkled posteriorly; but this, with the exception of the rings of growth, appears to me to result from pressure. The shells are equivalve, and have the external aspect of *Unionidæ* or *Mytilidæ*. (3.) I know of no instance in Nova Scotia of the occurrence of these shells in the strictly marine limestones, nor have any properly marine forms of Mollusca been found with *Naiadites* in the coal measures. (4.) The mode of their occurrence precludes the idea that they were burrowers, but favours the belief that they were attached by a byssus to sunken or floating timber. On the whole, I think that the balance of probability is in favour of the conclusion that they were brackish-water or fresh-water shells, allied to *Mytilidæ* or to embryonic *Unionidæ*.

* Supplement to Acadian Geology, 1860.

† Quart. Journ. Geol. Soc., vol. xix. p. 79.

‡ Neues Jahrbach, 1864. Geological Magazine, May 1865.

(1.) *Naiadites* (*Anthracoptera*) *carbonaria* (Dawson)—Fig. 42.—Hinge-line straight, more than one half the length of the shell; beak

Figs. 42 *to* 46.—*Species of Naiadites.*

Fig. 42.

Fig. 43.

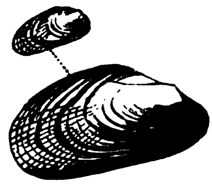


Fig. 44.

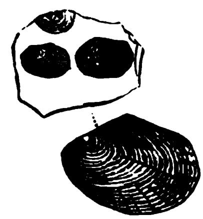


Fig. 45.

Fig. 46.

acute, in the anterior fourth of hinge-line; anterior margin abruptly rounded; ventral margin nearly straight, with a slight sinus; posterior margin broad and regularly rounded; shell thin, with distinct growth lines. When recent, the shell was probably somewhat tumid, but is usually flattened, and often much distorted by pressure, so that it is very difficult to obtain a specimen sufficiently perfect to be described or figured. Length of adult, an inch or more. This is the most abundant species in the Coal measures of the Joggins, beds of some thickness being often almost entirely made up of the valves. Fig. 31, p. 182 *supra*, represents an imperfect and distorted specimen. See also Fig. 22 in my paper on the South Joggins in the Journal of the Geological Society, vol. x. p. 39. This shell may possibly be the *Modiola Wyomingensis* of Lea (Journ. Ac. Nat. Science, 2d series, vol. ii.); but if so, his specimen is imperfect.

(2.) *Naiadites* (*Anthracomya*) *elongata* (Dn.)—Fig. 43.—Smaller than the preceding, and more elongated laterally; the beaks obtuse and more anterior; the hinge-line nearly straight and less than half the length; ventral margin slightly compressed; length, half an inch to an inch; common at the Joggins and Sydney, in the Middle Coal measures. See Fig. 23 in paper above cited.

(3.) *Naiadites* (*Anthracoptera*) *laevis* (Dn.)—Fig. 44.*—Broad ovate, extremely thin; beak about one-third of distance from anterior end. This species is smaller, more rounded, thinner, and with the

* Mr Salter thinks that this is identical with a species found in the Upper Coal measures of Manchester.

beaks more central, than No. 1. It occurs in a bed of shale at the base of the Middle Coal series at the Joggins.

(4.) *Naiadites arenacea* (Dn.)—Fig. 45.—Elliptical; twice as long as wide; beaks prominent, one-fourth from anterior end, which is compressed and rounded. In the Upper Coal formation at Pictou.

(5.) *Naiadites ovalis* (Dn.)—Similar in general form to No. 4, but much broader in proportion. See paper above cited, Fig. 24. It occurs in bituminous limestone, with cyprids, in the lower part of the Joggins Coal measures.

(6.) *Naiadites angulata* (Dn.)—Fig. 46.—Similar in general form and proportions to No. 4, but with more prominent beaks, a straight hinge-line, and an undefined ridge running backward from the umbo, and causing the posterior extremity to present an angular outline. Lower Coal formation at Parrsborough.

(7.) *N. obtusa* (Dn.)—As large as *N. carbonaria*, but remarkable for the broad and truncated form of its anterior end, giving it an approach to a quadrangular form. It is thin, and much marked by growth lines. Lower Coal measures, M'Lellan's Brook, Pictou.

II. *Spirorbis carbonarius.*—Fig. 47.—This little shell, which I described as a *Spirorbis* as long ago as 1845,* is apparently not specifically distinct from *Microconchus carbonarius* of the British Coal-fields.

Fig. 47. —*Spirorbis carbonarius; nat. size attached to Cordaites, and magnified.*

Its microscopic structure is identical with that of modern *Spirorbes*, and shows that it is a true worm-shell. It is found throughout the Coal formation, attached to plants and to shells of *Naiadites*, and must have been an inhabitant of enclosed lagoons and estuaries. Its occurrence on *Sigillariæ* has been used as an argument in favour of the opinion that these trees grew in sea-water; but, unfortunately for that conclusion, the *Spirorbis* is often found on the inside of the bark, showing that this had become dead and hollow. Beside this, the same kind of evidence would prove that *Lepidodendra*, *Cordaites*,

* Quart. Journ. Geol. Soc., vol. i. p. 326.

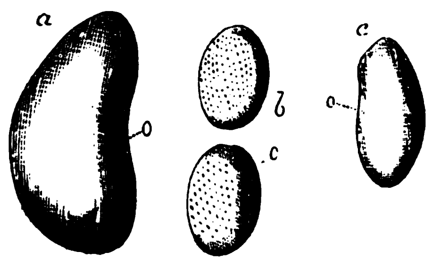
and ferns were marine plants. *Spirorbes* multiply fast and grow very rapidly; and these little shells no doubt took immediate possession of submerged vegetation, just as their modern allies cover fronds of *Laminaria* and *Fucus*.

As I have not met with a description of this little shell, I may state that it is dextral, with two and a half to three turns. It is attached throughout its length, and, when not compressed, presents a somewhat deep umbilicus. It is closely marked with beaded or unequal transverse ridges. It has, when young, a close resemblance to *Sp. caperatus*, M'Coy, from the Carboniferous limestone of Ireland; but this species has only two turns, and is sinistral.

This shell has been described by Goeppert as a fungus, under the name of *Gyromyces ammonis*.

III. *Crustacea*.—It appears, in the table above, that as many as fourteen beds of coal exhibit in their roofs shells of minute Entomostraca of the genera *Cythere* and *Bairdia* (Fig. 48),* and these occur

Fig. 48.—*Crusts of Entomostraca; nat. size and magnified.*



(*a*) Bairdia; (*b*) Cytherella inflata; (*c*) Cythere.

in such quantities that considerable beds of shale and bituminous limestone are filled with their valves. Professor Jones regards the species as marine or brackish-water; and the same remark will, I presume, apply to the crustacean *Diplostylus Dawsoni*, and a fragment of *Eurypterus* described by Mr Salter from Coal-group No. 8 of Division 4 of the Section, as well as to a second and larger species from Port Hood. Of the small Entomostracans there are several species, which Professor Jones has now in his hands for determination. No Estherians have yet been found in the Coal formation of Nova Scotia; but I have specimens of *Leaia Leidyi* from the Lower Carboniferous of Plaister Cove, and an undetermined *Estheria* from the same horizon at Horton Bluff. These will be described further on.

* One at least of these is identical with a British Carboniferous species.

The following are Mr Salter's descriptions of these interesting crustaceans, taken from his paper, Journal of Geol. Society, vol. xix. :—

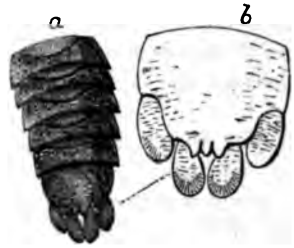
"DIPLOSTYLUS, gen. nov.

"Carapace unknown. Body segments arched, and with minute pleura. Tail segment large, triangular, spinose, with two pairs of simple ovate appendages.

"DIPLOSTYLUS DAWSONI, spec. nov. (Fig. 49).

"The portion preserved consists only of five rings and the broad telson; and these together are three-fourths of an inch long, and less

Fig. 49.—*Diplostylus Dawsoni.*



(*a*) Tail, nat. size; (*b*) terminal joint enlarged.

than half an inch broad at the widest part. The telson is somewhat narrower than the body-rings, broad above, and pointed behind, where it is notched into three spines, the centre one very short, the two on each side of it broad, and on their outer sides covering the attachment of two small obovate palettes. These palettes are a little oblique, narrower than their length, rounded at their posterior margin, and striated distinctly. Outside these, and much higher up on the sides, are a pair of broader notches, which give origin to a pair of small palettes, ovate and not broader at their ends, and striated obliquely; and above the insertion of these are a pair of broad, flat spines on the surface of the tail-joint.

"The body segments are transverse, the axis not much distinguished from the short, pointed, recurved pleura, with a narrow articular furrow, and strongly punctate on the exposed portions. The punctations (in the hinder segments only) are overhung by short plications: such punctations are observable in many Isopod Crustaceans.

"*Locality.*—Coal measures of the Joggins, Nova Scotia, in a plant-bed in the middle of the series.

"Having looked in vain for a similar pygidium among the large-tailed Isopods, and consulted Mr Spence Bate with a like result, he

referred me to a group of parasitic Amphipods (the *Hyperina*), among which there are a few forms* with tail segments coalesced and bearing appendages. These show a sufficient resemblance to warrant our referring *Diplostylus* provisionally to the Amphipod order. I am very much obliged to Mr Bate for this analogy (which would certainly have escaped me in Milne-Edwards's work). Mr Bate's late papers on the Amphipods (Ann. Nat. Hist., 1861) admirably illustrate this peculiar group.

"EURYPTERUS, a large species allied to *E. Scouleri*, Hibbert (Fig. 50).

"A mere fragment of a large body-ring, which nevertheless indicates a species nearly as large as the great Scotch *Eurypterus* (*E. Scouleri*, Hibbert).

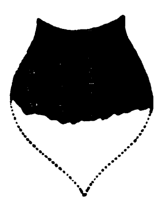
"The large 'teardrop-tubercles' along the hinder margin sufficiently show the nature of the ornament. These, in all probability, were replaced by spines on the carapace, as in the British Coal measure species.

"The carbonaceous film which remains in part on the surface, cracked (by shrinking) into minute areolæ, represents evidently a corneous substance, from which the animal matter has been dissolved away. The suggestion of Professor Huxley, that the large *Eurypteridæ* had a thick crust like that of *Limulus*, with but little calcareous matter, is most probably true.

"*Locality*—Coal measures, Port Hood, Cape Breton.

Fig. 50.—*Fragment of Eurypterus.*

Fig. 51.—*Tail of Eurypterus* (?).



"EURYPTERUS (?), tail of. (Fig. 51).

"This small specimen, found with the *Diplostylus* in the Joggins plant-bed, has evidently nothing to do with that genus. It is imperfect, but can hardly be supposed to be other than the caudal joint (broken) of a *Eurypterus* or allied form. It is, as usual in that genus, contracted at its origin, but swells out afterwards, in the manner of

* *Anchylomera, Typhis, Brachyscelus, etc.*

the tail-joint of *Slimonia* (*Pterygotus*) *acuminata.* There are no surface markings or marginal serrations."

Locality.—Coal measures, Joggins, N.S.

IV. *Fishes.*—Remains of fishes occur in connexion with eighteen of the coal-beds at the Joggins, usually in the roof-shales, though detached scales, teeth, spines, or coprolites, are of occasional though rare occurence in the coal itself, especially where the latter passes into coarse coal or carbonaceous shale. One thin bed, No. 6 of Division 4 of the Section, is full of remains of small fishes. It is hard and laminated, and roofed with a calcareous bed full of remains of aquatic animals. It has a true stigmarian underclay. I suppose it to have been a swamp or forest submerged and occupied by fishes while its vegetation was still standing. It contains remains of fishes of the genera *Ctenoptychius*, *Diplodus*, *Rhizodus*, and *Palæoniscus*. It also contains *Cythere*, *Naiadites*, and *Spirorbis*. In the other beds which contain fish-remains, most of these consist of small *Lepidoganoids*, but there are occasional teeth and scales of large species of *Rhizodus*, and also teeth of Selachian fishes of considerable size.

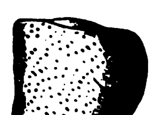
Among these I have in my collection a tooth of a *Ctenoptychius* (Fig. 52), differing from any species of which I have seen a description.

Fig. 52.—*Tooth of Ctenoptychius cristatus, N.S.; nat. size and magnified.*

It is two lines in length, with fourteen sharp denticles, much compressed, and with a narrow base. Another very fine tooth found in these beds appears to belong to M'Coy's genus *Conchodus* (Fig. 53). It has seven

Fig. 53.—*Tooth of Conchodus plicatus, N.S.*

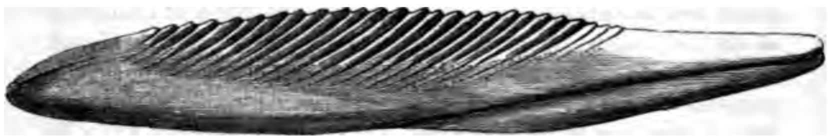
Fig. 54.—*Tooth of Psammodus.*



strong angular ridges, with a slightly granulated and obliquely wrinkled

surface, and is an inch and a half in length, and about seven lines wide in the middle. The anterior edge is slightly and regularly rounded, and the posterior edge forms an obtuse angle rounded at the apex. Other teeth are referable to the genus *Psammodus* (Fig. 54). There are also spines of the genus *Gyracanthus* (Fig. 55), though not of the

Fig. 55.—*Spine—Gyracanthus duplicatus, N.S.*



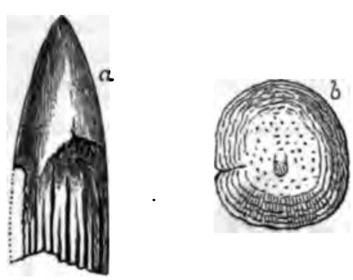
magnificent proportions of a specimen found by Mr Barnes in Cape Breton, and measuring 22 inches in length (Fig. 55*a*). Not being

Fig. 55*a*.—*Spine—Gyracanthus magnificus, N.S., reduced.*

able to identify these fossils with any described species, I have assigned to them provisional names until further specimens shall render them better known.

Many scales and other remains of fishes occur in the roof of the main coal at Pictou, and also in the bed included in that coal-seam which afforded the reptile *Baphetes planiceps*, and which is evidently in the manner of its formation of the same general character with the Modiola and Cypris shales of the Joggins. Most of these belong to the genus *Rhizodus*, and to a species not distinguishable from *R.*

Fig. 56.—*Rhizodus lancifer* (?).



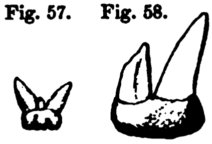
(*a*) Tooth; (*b*) scale.

lancifer, Newberry (Fig. 56), of the Coal-field of Ohio. There is

also a fine species of *Diplodus*, which appears to be new, and which I have named *D. acinaces*. Its lateral denticles are compressed and sharp-edged, but scarcely crenulated, and both bent in the same direction. Middle cone obsolete; base large and broad. One denticle is usually much larger than the other. The greatest diameter of the larger denticle is to its length as one to three. A tooth of ordinary size measures six lines from the lower side of the base to the point of the longest denticle, and the base is four lines broad (Fig. 58). I regard as probably belonging to this fish certain cylindrical spines found in the same bed. They are about half an inch in diameter, with nearly central canal two lines in diameter, and are marked externally with parallel longitudinal striæ.

Among fossils from Pictou forwarded to me by Mr Poole, there is a new *Diplodus* (*D. penetrans*), Fig. 57. This is smaller than *D. acinaces* of the Main Coal. Its height is about two and a half lines, and the breadth nearly the same. The lateral points are half as broad as long, and flattened; rhombic in cross section at the base; serrated, especially at the outer and lower margins. They diverge at an angle of 35° to 40°, and the central denticle is small and conical. The base is broad and strongly lobed. These teeth occur in the roof of beds of coal near to and above the New Glasgow conglomerate, and in the roof of the Main Coal.*

Fig. 57. Fig. 58.



Teeth of Diplodus.

In the same collection is a small tooth of *Ctenoptychius* with eight denticles;—the specimen is an imperfect impression. There are also remains of several ganoid fishes. One of these is a conical curved tooth, half an inch long, smooth on the convex side, and marked on the concave side with five spiral ridges. It probably belongs to the genus *Rhizodus*. With it are scales, possibly of the same fish, which have the punctures and striæ of the genus *Osteoplax* of M'Coy. There are also two remarkable flattened sabre-shaped spines, one inch and a half in length, and resembling in general form the Devonian *Machæracanthus*. Several rounded scales have the characters of those of *Rhizodus*, and there are numerous scales and other remains referable to *Palæoniscus* and allied genera. These last in the Albion measures, as at the Joggins, abound in the bituminous shales and thin coals.

Notwithstanding the abundance of these remains of fishes, their dislocated condition opposes great obstacles to their satisfactory study. They all occur in the same beds, usually rich in vegetable matter, which contain the shells of *Naiadites* and the *Cythere* and *Spirorbis*.

* These species were described in "Supplementary Chapter," 1860.

Consequently they must have been capable of subsisting in the brackish and impure water of the coal creeks and lagoons. The smaller ganoid species would find in these abundance of worms, small crustaceæ, and larvæ of insects on which to feed; and if, like the modern ganoids of our North American rivers, they were provided with a lung-like air-bladder, they could subsist in stagnant water deprived of its free oxygen by decomposing vegetable matter, conditions under which the ordinary ctenoid and cycloid fishes, had they existed in the Coal formation period, would have perished. The larger ganoids and the shark-like Diplodonts no doubt preyed upon the smaller fishes, as the abundant scales seen in their coprolites prove. The flat-toothed, shark-like Psammodus and Conchodus may have ground up the shells of *Naiadites*, which probably hung in countless multitudes on the floating and sunken timber of these coal lagoons and creeks. Lastly, when these fish died, the millions of little Cytheres and Bairdias, by removing every particle of flesh and ligament, would scatter the scales and bones over the bottom of the waters, to be embedded in the black ooze.

CHAPTER XIII.

THE CARBONIFEROUS SYSTEM—*Continued.*

INLAND EXTENSION OF THE COAL MEASURES OF THE JOGGINS—SHORES OF NORTHUMBERLAND STRAIT—USEFUL MINERALS OF CUMBERLAND.

THE beds that appear at the Joggins can be traced eastward for many miles, and reappear with a very similar arrangement in the banks of the inland streams on their line of strike, as, for instance, on the Hebert River and Macean River; on the latter of which some of the Joggins beds appear ten miles from the coast. They no doubt extend, with some modifications in the details, quite to the coast of Northumberland Strait. On this coast, however, the rocks are not so well exposed as on the shores of Chiegnecto Bay, and they have been disturbed by lines of fracture, extending from the great line of elevation of the Cobequid Mountains.

In the intervening country the covering of soil prevents the geological traveller from observing much, except the ridges produced by the outcropping edges of the harder sandstones. The only portion of this inland region in which important coal measures have been observed is at Springhill, about twenty miles eastward of the Joggins coast, where it would seem that the great synclinal seen on the coast section runs out to the surface, presenting a narrow trough-shaped arrangement, accompanied by some disturbance of the beds.

At Pugwash, we find large beds of limestone and gypsum, the former with Lower Carboniferous shells; among which are the *Productus semireticulatus*, and a similar but more finely striated species, the *P. cora*. There are also joints of *Encrinites*, a little *Aviculopecten* or scallop, and a smooth shell, *Terebratula sacculus*, belonging to the same tribe with the Productæ, but more closely allied in form to the few species of that tribe which inhabit the existing seas. This limestone is of good quality, and has been extensively quarried. It dips to the S.W. On the shore in the vicinity a series of sandstones and brownish shales appear, also with S.W. dips. Associated with them are some beds of gray and black shale, with leaves of ferns and *Cordaites*. The limestone is again seen at Canfield's Creek, and there

it is associated with gypsum. The dip is S.S.W. These Pugwash beds are evidently Lower Carboniferous, and if the same regularity that we have observed at the Joggins prevailed, would be associated with a series of Coal formation rocks regularly succeeding them. A portion of such a series does appear in ascending Pugwash River, but in proceeding to the eastward we find that the centre of the trough is broken up by a dislocation or anticlinal line, extending to Cape Malagash, which causes the coal measure rocks to be ridged up in such a manner that two narrow troughs with an intervening anticlinal appear to occur between Pugwash and the Cobequid Hills. On the east side of Pugwash Harbour we find gray sandstones, apparently of the Upper Coal formation, in very thick beds, dipping to the north, and containing prostrate trunks of carbonized trees and Calamites. The shore runs nearly in the direction of the beds, and the gray sandstones in consequence form a sort of sea-wall sloping toward the strait, and extending from Pugwash to Oak Island. Under these sandstones are beds of gray shale, with fossil ferns and a small seam of coal; and these are again underlaid by dark red, brown, and mottled sandstones and shales. On the shore of Wallace Harbour there are gray sandstones and gray and brown shales, with high dips to the north-east; they are far beneath the beds seen on the Gulf Shore, and probably belong to the Middle Coal measures, possibly to their lower part. They contain at one place a thin seam of sulphurous coal, and chalybeate and sulphurous springs rise from them. The whole of these beds, as well as others seen farther inland, bear a striking resemblance, as far as can be observed, to those of the Joggins section.

Sandstones and shales of the Coal formation prevail along the coast between Wallace and Cape Malagash, and there present some appearances worthy of notice, more especially the association of limestone, marine shells, and gypsum, with beds containing trunks of fossil coniferous trees, and the occurrence of coal measure beds in a vertical position, or disturbed as far as possible from their original horizontality. At M'Kenzie's Mill, not far from the eastern extremity of Wallace Harbour, the following curious succession occurs, in descending order:—

	Feet.
Gray limestone with *Productus cora*, *P. semireticulatus*, and *Aviculopecten simplex*, the cavities of the shells filled with crystalline gypsum	2
White small-grained crystalline gypsum	10
Reddish shale and sandstone with layers of arenaceous and concretionary limestone	40

	Feet.
Gray sandstone and shales with some reddish beds. One of the gray sandstones is filled with trunks and branches of fossil trees, fossilized by carbonate of lime, and showing under the microscope a very perfect structure of the Araucarian type . . . . about	150

Here we have, on a small scale, some of the principal features of the Lower Carboniferous series, associated with vegetable remains similar to those found usually at a much higher level in the Carboniferous system. The beds at this place dip S. S.W. 20°; but a little farther to the north there are sandstones and conglomerates, also of the Carboniferous series, dipping to the N.E.

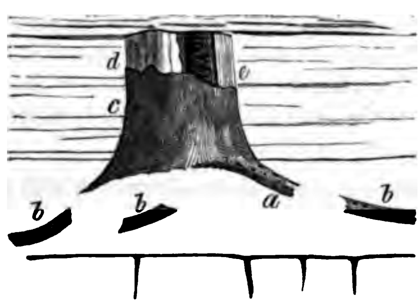
Proceeding along the coast to the north-east, we find the gray sandstones containing fossil trees and thrown quite on edge. As the strike of the beds corresponds nearly with that of the shore, large surfaces sometimes stand up along the face of the cliff like walls, and on these are distinct ripple-marks and worm-tracks, produced when the sandstones were beds of incoherent sand, but now, in consequence of the hardening and disturbance of the sandstone, forming sculptures on a vertical wall. A little further on, the same beds are seen dipping to the north at an angle of 45°, and containing abundance of fossil wood and some *Calamites*. A portion of the shore is then occupied by a salt marsh, and beyond this we have a considerable series of coal measure beds at the extremity of Cape Malagash, dipping south at an angle of 40°. Cape Malagash, as before stated, thus appears to be in the line of a subordinate anticlinal, ridging up the Coal formation rocks, but not, like the more important anticlinal to the northward, bringing up the Lower Carboniferous series. That the reader may have an opportunity of comparing these beds with those of the Joggins, at the other extremity of the same coal-field, and sixty miles distant, I shall give a section of them in descending order.

	Feet.
Brownish red sandstones and shales alternating with gray sandstones, one of them containing pebbles of white quartz, about	600
Dark gray limestone	2
Gray and reddish sandstones	50
Dark gray limestone	3
Gray sandstones	50
Reddish sandstones and shales	not well seen.
Gray arenaceous shale, Fern leaves, and *Cordaites*	6
Underclay with *Stigmaria*, and an erect stump with Stigmaria roots, penetrating bed above	3

	Feet.
Dark gray limestone	3
Alternations of gray and reddish sandstone and shale. In the lower part a bed of *coal* six inches thick, with Stigmaria underclay . . . . about	300
Gray sandstone	20
Alternations of reddish sandstones and shales and gray sandstone, with thin layers of clay ironstone and a layer of coaly shale . . . . about	300

This is evidently very like some of the more barren parts of the Joggins shore, especially near the lower part of the coal measures. I may remark, however, that if the section at Malagash was exposed in a cliff like that of the Joggins, I have no doubt that more beds with erect plants would appear. The erect tree mentioned in the section was described and figured by me in the Proceedings of the Geological Society in January 1846. Mr Binney had described a similar specimen found in Lancashire in June 1845; and before the close of 1846, Mr R. Brown of Sydney had described still finer instances of the same kind from the Sydney Coal-field. These were the three first instances in which the Stigmaria was ascertained to be the root of the Sigillariæ of the Coal period; and even these were not altogether sufficient to dispel the doubts of some geologists. As the Malagash tree is thus an historical monument in the progress of geology, I give a sketch of it in Fig. 59.

Fig. 59.—*Erect Sigillaria at Cape Malagash.*



(*a b*) Stigmaria roots. (*c*) Bark marked with furrows.
(*d*) Woody surface with indistinct ribs. (*e*) Internal axis.

On the south side of Malagash Cape and head of Tatamagouche Bay, the Coal formation rocks dip to the southward, but are not well exposed; and at Tatamagouche Harbour we find them dipping to the

north, which they continue to do as far as the base of the Cobequid Hills at New Annan. Cape Malagash thus forms an anticlinal ridge, which extends far to the westward into the interior of Cumberland; and if we consider the limestone at M'Kenzie's as the equivalent of the Pugwash and Napan limestones, then the trough between it and the New Annan Hills corresponds to the Joggins trough, though narrower, and the northerly dipping beds of the Gulf shore correspond to those north of the Joggins in New Brunswick. It is, however, more probable that the great Cumberland trough is here, as already hinted, split into two by the intervention of the Malagash anticlinal. Unless the more important parts are concealed by the imperfection of the sections, the whole Carboniferous series appears here to be less fully developed than on the western coast of the county.

The beds seen with northerly dip at Tatamagouche, and thence to New Annan, have the aspect of those of the Upper Coal formation. They constitute a belt extending along the coast and connecting the Cumberland coal area with that of Pictou. Though beyond the limits of the county of Cumberland, they may be noticed here.

At the mouth of the French River are gray sandstones and shales, containing a few *Endogenites*, *Calamites*, and pieces of lignite, impregnated with copper ores. Beneath these appears a series of brownish red sandstones and shales, with a few gray beds, occupying, in a regular descending series, about six miles of the river section. They contain, in a few places, nodules of copper glance (gray sulphuret of copper); they are often rippled, and contain branching fucoidal marks. On one of the rippled slabs I found marks consisting of four footprints of an animal. They were three inches and a half apart, and each exhibited three straight marks as if of claws. These were described in 1843; and in the following year I discovered at the same place another series of footsteps of different form. Neither of these were sufficiently well marked to give any definite information respecting the nature of the animal that produced them; but I am now convinced that they must have been the traces of reptilian animals. In my paper sent to the Geological Society in 1844, I find the following remarks:—

"When examining the red sandstones near Tatamagouche last summer, I found in one of the beds a few footmarks of an unknown animal, specimens of which were sent to this society. They were mere scratches made by the points of the toes or claws, and therefore could give few indications of the form of the feet which produced them. Their arrangement, however, appeared to indicate that the animal was a biped, and their form is quite analogous to that of the marks left by our common sandpiper, when *running* over a firm sandy

P

shore. On a subsequent examination of the same place, I found a series of footmarks of another animal, and obtained a slab with casts of eight impressions, which I send with this paper. In this specimen the tracks are somewhat injured by the rain-marks which cover the slab, and the clay in which they were made was probably too soft to give good impressions; it has, however, preserved a furrow which must have been caused by the body or tail of the animal trailing over it. Many of the beds in the neighbourhood of that containing these footmarks are rippled, rain-marked, or covered with worm-tracks; and as such indications of a littoral origin are not infrequent in other parts of the Newer Coal formation, it may be anticipated that many interesting relics of terrestrial animals will in future be discovered. At present, however, as no quarrying operations are carried on in the red beds, it is difficult to obtain access to the surfaces on which tracks might be expected to occur. The only vegetable remains found in the red sandstones of Tatamagouche are some of those irregular branching stains which have been considered as fucoidal marks; but in a bed of gray sandstone above the strata containing tracks, I found *Calamites*, *Endogenites*, *Stigmaria ficoides*, and fragments of carbonized wood. In a fragment from a dark calcareous bed near this place, I found a portion of a fossil plant covered with shells of a species of *Spirorbis*, and a few small scales of ganoid fishes."

It will be observed that *rain-marks* are mentioned as found with these footsteps, and I have now in my collection specimens from this place, I believe the first ever observed in the Carboniferous system; though much finer specimens were found shortly afterwards by Mr Brown at Sydney, and described by him and by Sir C. Lyell.

In the French River section, the northerly dips of the Coal measures increase in approaching the hills, the lowest beds dipping at an angle of 30°. Not far from the base of the hills, there is a small bed of coal, with some gray shales and sandstones and a thin bed of limestone.

Useful Minerals of the Cumberland Coal-field.

Coal.—The principal deposit of this mineral now worked in Cumberland is the Joggins main seam, consisting of two beds, three feet six inches and one foot six inches thick, with a clay parting between, varying from one foot to a few inches. It is a free-burning bituminous coal of fair quality. It is extracted by two shafts worked by horse-gins, and the coal is carried to the loading pier by a railway incline. The mine is drained by a level run out to the shore, and consequently is not worked below the level of high tide. The

General Mining Association are the lessees of this mine. The quantity of coal shipped in 1851 was only 2400 chaldrons. In 1864 it had risen to 6053 tons, and in 1866 to 8478. It was exported principally to St John, New Brunswick.

Taking into account the comparative thickness of the seams, and the facilities for extraction and shipment, there can be no doubt that the bed at present worked is the best in the section; which, as we have already seen, is remarkable for the great number and small thickness of its coal-seams. It seems certain, however, that some of the others, especially the principal beds in Groups XI. and XIII. of the section, might be mined with profit. Since the publication of the former edition of this work one of these, No. 29*a* of the section, has been opened. The great disadvantage on the Joggins coast is the want of safe anchorage for shipping, which can be protected only by expensive piers and breakwaters. Since the expiry of the exclusive privileges of the General Mining Association, attempts have been made to obviate this disadvantage by opening mines on the banks of the Hebert and Maccan Rivers. Six companies have opened works in this part of the district, under the names of the "Victoria," "Maccan," "Chiegnecto," "Lawrence," "St George," and "New York and Acadia" Mines. The beds which they work appear to be of similar character with those of the Joggins, of which they are the direct continuation. It is questionable, however, whether the shafts of these new mines have yet opened the best beds of coal, nor does it seem certainly known with which of the seams at the Joggins those opened correspond. At the Victoria Mine, according to Mr Rutherford, there are three seams. The upper seam is sixteen feet above the middle, and this fifty-three feet above the lowest. The upper seam is one foot ten inches thick, the middle three feet, and the lower has three feet of coal divided by two partings of fire-clay. These beds are probably on the horizon of Coal-groups 29 and 30 of the coast section. According to the same authority, the Lawrence Mine, which adjoins the Victoria on the east side of Hebert River, has opened two seams of coal, each two feet six inches thick, and separated by a vertical thickness of twenty feet. In the Maccan Mine, eastward of the Lawrence, two seams have been opened, only one of which, two feet four inches thick, is at present worked. The Chiegnecto, St George, and New York and Acadia Mines are all on the same seam, which presents different characters from those in the above-mentioned mines. Its section in the Chiegnecto Colliery is thus given by Mr Rutherford:—

	Ft.	in.
Coal (coarse)	2	2
Shale	0	6
Coal	2	1
Slaty band	0	1½
Coal	1	5½
„ (coarse)	0	4
Shale	1	3
Coal	1	2
Slaty band	0	2
Coal	3	6
	12	9

This bed contains no less than ten feet eight inches of coal, and is consequently the thickest yet observed in this section. It may be compared with Coal-group 29 of the coast section. In the adjoining area, the St George, the amount of coal appears to diminish to seven feet eight inches, while the clay partings increase. This fact shows how hopeless it is to attempt to identify coal-seams, even a few miles distant, by their minute structure. It seems, however, not unlikely that all the beds above referred to, as worked on the Hebert and Maccan Rivers, belong to the *lower* series of workable seams at the Joggins coast, and that the exact equivalent of the main seam has not yet been discovered. Still I would not venture to be at all positive as to this; but merely throw it out as a suggestion to explorers, who might perhaps discover the outcrop of the main seam to the southward of the mines now worked.

The quantity of coal extracted in 1866 from the new mines above mentioned was 9374 tons, making, with that from the Joggins mines, 17,852 tons.

About twenty miles south-east of the Joggins shore, at a place called Springhill, Coal measures appear with a dip to the north, indicating, with their position not many miles from the base of the Cobequid Hills, that they belong to the southern side of the Cumberland trough. I have had no opportunity of examining the coal-seams of this place, but one of them is variously stated at eight and twelve feet in thickness, and the coal is of good quality. The Springhill bed is at too great distance from navigable water to permit it to be mined at present for exportation. It forms part of the reserve stores of coal, waiting for their full development till railways extend across the country, or till domestic manufactures demand supplies of mineral fuel within the province. The present inland demand might, however,

permit it to be mined on a small scale; and could a railway be constructed, it might be profitably employed in smelting the rich iron ores of the Londonderry mines. Should railway communication be established between Cumberland and Halifax on the one side, and New Brunswick on the other, this coal area would at once become important.

The following assays show the qualities of samples of Joggins and Springhill coal examined by me; but it must be observed that the specimen from Springhill was from the outcrop of the seam, and therefore probably injured by weathering.

Assay of Joggins Coal from the Main Seam.

The specimen is bright coal of uniform texture, with straight joints containing films of iron pyrites and calcareous matter.

Moisture	2·5
Volatile combustible matter	36·3
Fixed carbon	56·0
Reddish-gray ashes	5·2
	100·0

Assay of Springhill Coal.

The specimen is a compact coal, less bright than that of the Joggins, and without films of pyrites, though it contains some sulphur intimately mixed with it.

Moisture	1·8
Volatile combustible matter	28·4
Fixed carbon	56·6
Reddish ashes	13·2
	100·0

From the character given of the Springhill coal by persons who have used it, I should infer either that its quality has been overrated, or that my specimen is inferior to the average quality.

The above assays show that the Joggins coal much resembles that of Sydney, C.B., while the Springhill coal is more like that of Pictou. See assays of these coals farther on.

The structure of the Cumberland coal-field warrants the expectation that the Springhill seam may be traced toward the coast of Chiegnecto Bay, perhaps to the vicinity of Apple River, where a very small bed of coal has been discovered, and also in the opposite direction. Attempts

which have been made by a mining engineer in the service of the General Mining Association to effect the former of these results, have, however, been unsuccessful; and it would appear that the beds in the vicinity of Springhill are in a much more disturbed condition than those on the Joggins shore.

In like manner, it is a perfectly fair inference that the seams which appear in the coast section of the Joggins, must extend along the northern side of the trough, far into the interior of the country; though whether they improve or deteriorate in their eastern extension is not at present known. It appears certain, however, that the coal measures are less fully developed on the coast of Northumberland Strait than on the western coast, and the seams which have hitherto been found in them are very small.

It may, therefore, be inferred, that in the event of the interior of the Cumberland district being opened up by railway communication, the localities offering the greatest prospects of valuable discoveries are,—*1st*, The line of country extending E.S.E. from the Joggins toward the branch of the River Philip called Black River; and, *2d*, A line extending east and west, and passing through Springhill.

Clay Ironstone occurs in the Joggins section and elsewhere, in balls in the shales, and in irregular bands. None of these deposits are at present of any economical importance; though, could smelting works be established in connexion with the Londonderry ores, a considerable additional supply of clay ironstone could be procured from the Coal measures, and might be of much value.

Grindstone is one of the most important productions of the Cumberland coal-field. I have already referred to the mechanical qualities on which this rock depends for its value. The principal localities of the quarries are Seaman's Cove and Ragged Reef; the beds at the former being below the productive Coal measures, those at the latter above them. In smaller quantities, grindstones are obtained from a number of other beds and reefs along the coast, and also from the continuation of these beds on the estuary of the Hebert River, and from the geological equivalents of the beds at Seaman's Cove, where they reappear in New Brunswick. Forty-six thousand four hundred and ninety-six grindstones were made in Nova Scotia in 1861, the greater part in Cumberland. Grindstones are also quarried in the sandstones on the eastern coast of Cumberland; and at Wallace there are valuable beds of freestone which have been quarried for exportation.

Limestone and *Gypsum* abound in the line of country extending from Minudie to Pugwash and Wallace. The former especially occurs in very thick beds at Napan River and at Pugwash; and these are

also the principal localities of gypsum, which does not, however, appear to be so abundant in the Lower Carboniferous rocks of this county as in those of Hants and Colchester.

A singular variety of limestone occurs in a number of places on the Joggins shore. It is the black *bituminous* limestone, so often referred to in the section. This substance, though not in sufficiently thick beds to compete with the larger Lower Carboniferous limestones for ordinary purposes, is the most valuable limestone in the county for application as a manure, in consequence of the quantity of phosphate of lime contained in it, in the form of scales and bones of fish. In consequence of its containing this valuable ingredient, it is worth to the farmer more than three times the price of ordinary limestone, and I have no doubt that it will be extensively worked for agricultural purposes, when the use of mineral manures becomes more general among the farmers of Cumberland. It is possible that even at present the lime from the richest of these beds would be sufficiently appreciated on trial to allow them to be profitably worked.

The soils resting on the Carboniferous rocks of Cumberland are very various in their quality, and run in lines across the county in correspondence with the strikes of the groups of beds from which the materials of the surface soils have been derived. Rich loamy and calcareous soils generally accompany the limestones, gypsums, and marly clays and sandstones of the Lower Carboniferous system. The soils of the coal measures vary from light and sometimes stony sands to stiff clays. The Upper Coal formation produces soils approaching somewhat to those of the Lower Carboniferous series. Hence along the north side of the Cobequid Hills we have a broad band of good soil, and a similar one extending across the northern part of the county, while between these are alternate belts of poor and rich soils; almost the whole, however, being sufficiently deep and friable to be cultivable.

The great fertility of the marsh-lands of the western coasts and rivers, and the almost exclusive attention of the population on many parts of the eastern shore to lumbering and shipbuilding, have caused the value of the upland soils of Cumberland to be much underrated; but they are now constantly rising in the estimation of the people of the county, and will do so more and more as improved methods of cultivation become more generally diffused and appreciated.

CHAPTER XIV.

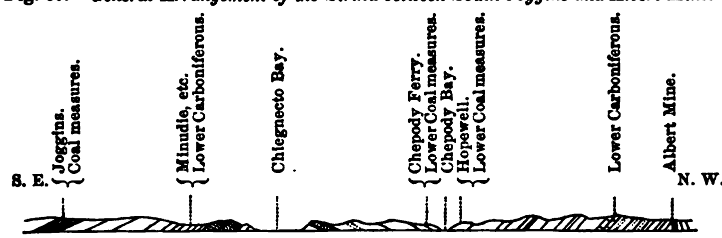
THE CARBONIFEROUS SYSTEM—*Continued.*

CARBONIFEROUS DISTRICT OF NEW BRUNSWICK—GENERAL OBSERVATIONS—STRUCTURE OF THE COAL-FIELD—LOWER CARBONIFEROUS ROCKS—FOSSILS—USEFUL MINERALS.

THE coal measures of the Joggins, dipping to the south-west, extend in the direction of their strike across Chiegnecto Bay to Cape Meranguin and the North Joggins, where the gray and red sandstones of the Millstone-grit and lower portion of the Coal measures are well seen on the coast, dipping S. 10° W. at an angle of 45°. On tracing these beds a little to the northward, they become vertical and dip to the north, forming an anticlinal. This anticlinal appears to extend to the north-westward up the bay, for at Fort Cumberland the first rocks that we see on entering New Brunswick are coarse gray sandstones dipping to the northward. This dip continues as far as the east side of the Petitcodiac River, where the highest beds are seen at the ferry below Dorchester. They are gray sandstones, with *Calamites*, *Sternbergia*, and trunks of coniferous trees; and beneath them, extending along the coast to the southward, is a great series consisting principally of reddish beds. I have no doubt that the whole of these beds belong to the older part of the Coal formation. Nothing newer is seen in this neighbourhood; for at Dorchester and Fort Folly Point, and at Hopewell, on the opposite side of the ferry, the same gray sandstones reappear with southerly dips, and with fossils of the same species. The dip varies from S.S.E. to S.E. If we follow this series in descending order to the northward, up the Memramcook River, we soon come to conglomerate, limestone, and thin-bedded bituminous and calcareous shales, all belonging to the Lower Carboniferous series. On the west side of the Petitcodiac, we find a similar descending series toward the great metamorphic band ending in Shepody Mountain, and which consists of rocks older than the Carboniferous system. The order of succession seen here is as follows, though there may be important omissions in the list, as the sections are not continuous:—

1. Gray sandstone, often coarse and pebbly, with shales and conglomerate, Hopewell Ferry, etc. These beds perhaps correspond to the great sandstone ledges of Seaman's Quarries, Joggins. They may be traced through Albert County to the south-west for a considerable distance.
2. Reddish sandstones and shales.
3. Limestone and gypsum.
4. Red sandstone and conglomerate.
5. Gray and dark-coloured conglomerate.
6. Calcareo-bituminous shales of the Albert Mine, Hillsborough. These beds appear here to lie at the very base of the lower Carboniferous series. (See Section, Fig. 60.)

Fig. 60.—*General Arrangement of the Strata between South Joggins and Albert Mine.*



The Lower Carboniferous and Millstone-grit series of southern New Brunswick thus appear to consist of the same elements as in the part of Nova Scotia just described, with the exception of the occurrence of a representative of the Lower Carboniferous Coal measures in the bituminous shales of Hillsborough. In the vicinity of the Albert Mine these seem to be the lowest member of the series; but Professor Bailey describes a lower conglomerate as underlying shales, similar to those of Hillsborough, farther west at the Pollet River. In 1852, I determined the geological age of the Albert deposits on stratigraphical grounds, and since that time Mr C. F. Hartt has added the confirmatory evidence of fossils, having found specimens of *Cyclopteris Acadica* and *Lepidodendron corrugatum*, the characteristic plants of this portion of the Carboniferous series, as seen in the cliffs at Horton Bluff in Nova Scotia, to be described in the sequel.

At the Albert Mine, the geologist stands at the extremity of a long range of metamorphic (Devonian) rocks, stretching along the south coast of New Brunswick, and terminating in Shepody Mountain. The Lower Carboniferous rocks bend around the end of this ridge, and are thrown off from its north-east and north-west sides. On the former they extend in a belt of no great breadth to Salisbury Cove, beyond

which they appear only in detached patches, the most western of which, on the coast eastward of St John, are those of Quaco and Gardiner's Creek. On the northern side these beds occupy a broad belt of country, extending along the valleys of the Petitcodiac and Kennebeckasis Rivers, and in part limited on the north-west by another metamorphic ridge, stretching from the great area of such rocks lying on the St John River to the eminence known as Butternut Ridge. The belt thus limited, and which extends for nearly eighty miles, with a breadth of from sixteen to twenty miles, appears to consist wholly of beds of the three lowest divisions of the Carboniferous period. The Lower Carboniferous Coal measures and their associated conglomerates skirt the northern side of the Shepody range, and are succeeded by the marine limestones and gypsums. These appear to be brought up by an undulation in the middle of the valley at Sussex Vale, and they reappear on the north side of the Kennebeckasis, skirting the exterior of the metamorphic belt of the Kingston series to Butternut Ridge already mentioned.

Doubling around the metamorphic promontory near Butternut Ridge, the Lower Carboniferous outcrop extends in a narrow and somewhat curved band to the west, till it reaches Oromocto Lake and the Magaguadavic River, near the line of the St Andrew's Railway. It then bends sharply to the north-east, and, in so far as known, runs directly, though with many minor curves and detached outliers, to the Bay de Chaleur, skirting the margin of the broad Silurian area of northern New Brunswick. One of the most important outliers is that on the Tobique River.* In so far as this series has been examined, it has been described by Professor Bailey and his associates† as composed of red conglomerates, red sandstones, and red shales, with beds of limestone and gypsum, and in places penetrated and overlaid by trappean rocks, by which some of the beds appear to have been considerably altered. These eruptions of volcanic rock I suppose to be of much older date than those of the Trias, and to be similar to those which occur in the Lower Carboniferous of Nova Scotia, and which will be described in the sequel.

From the above description, it appears that the line of outcrop of the Lower Carboniferous is bent upon itself, forming an angle of about 45°, each limb of which extends for about 150 miles to the waters of the Gulf of St Lawrence. The great triangular area thus limited, except where connected with the Cumberland area in Nova Scotia by an isthmus a few miles in breadth, includes an area of nearly 6000

* Hind's Report, p. 62.
† Report on Geology of Southern New Brunswick, 1865.

square miles, and is occupied by rocks of the Coal formation. Under these rocks the Lower Carboniferous beds no doubt extend; and in some localities they are in part exposed at the surface by the slight undulations which affect the widely distributed and nearly horizontal beds of this extensive Coal formation area.

In the first edition of "Acadian Geology," I did not attempt any general description of the New Brunswick Carboniferous area; but since that time the researches of Professor Bailey and of Messrs Matthew and Hartt, and those of Professor Hind,* with the facts previously published by Sir W. E. Logan, and those in the MS. notes of the late Dr Robb, kindly placed in my hands by his brother, Mr C. Robb of Montreal, have given much additional information. I have also had opportunities of examining the fossil plants collected by Sir W. E. Logan and Mr Hartt, and of visiting some additional portions of this area. To enter into the details of the new matter thus collected would far exceed my present space. I shall, under the following heads, merely endeavour to present some of the more important facts and conclusions:—

1. *Structure of the Coal-field of New Brunswick.*

The coal area of New Brunswick is remarkable, as compared with Nova Scotia, for the flat and undisturbed condition of its beds, and for the comparative prevalence of sandstones. Indeed, in so far as the appearances present themselves to a cursory observer, the whole of the Coal formation area of New Brunswick may be characterized as a flat expanse of somewhat coarse gray sandstone. Other beds, however, are not wanting, as conglomerate, red sandstone, and shales of various qualities; but, from the flatness of the beds and general small elevation of the surface, they are not very obvious.

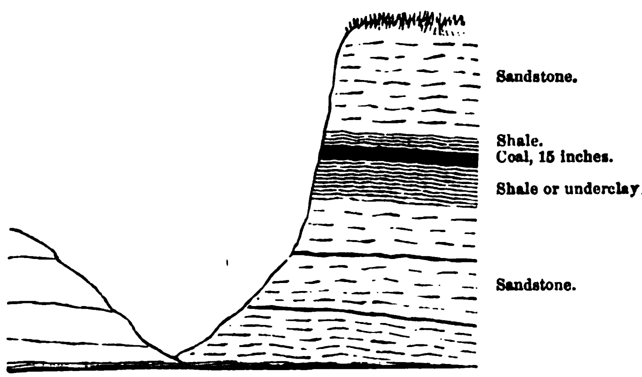
In attempting to estimate the thickness and relations of the Coal formation area of New Brunswick, the facts observed on the northern coast of the province, between Bathurst and Bay Verte, are of the utmost importance. I have not myself explored this region, having seen it only at a few points; but Sir William Logan has given a detailed section of a portion of it in the vicinity of Bathurst, and much information is contained in the MS. notes and sections of the late Professor Robb of Fredericton referred to above.

Near Bathurst, the Lower Carboniferous or "Bonaventure" Formation, as it has been named by Logan in its extension into Canada, is represented by thick beds of red and gray conglomerate, including

* "Observations on the Geology of Southern New Brunswick," by Professor Bailey, M.A.; Preliminary Report, by H. Y. Hind, M.A., etc.

red and gray shales, in one of which occur remains of plants, fossilized by the gray sulphuret of copper, in the manner often observed in the Carboniferous rocks of Nova Scotia. Over these are reddish sandstones of considerable thickness, succeeded by gray sandstones and shales, including underclays, many fossil plants, and two thin beds of coal. The thickness of these, as measured by Sir W. E. Logan, is about 400 feet. These beds appear to be on the north side of an anticlinal which runs out toward Shippegan. South of this, according to Professor Robb's observations, the dip, though slight, is to the southward, and the gray and nearly horizontal sandstones of the Miramichi River, which contain fossil plants and a thin seam of coal, are in the centre of a great flat synclinal which occupies the greater part of the breadth of the coal-field. South of the Miramichi, the gray sandstones, with an opposite dip, extend to Richebucto, where a small bed of coal occurs at a place called Coal Brook, with the accompaniments represented in Fig. 61.

Fig. 61.—*Section on Coal Creek near Richebucto.*—Dr Robb.



Under this, and extending to Buctouche, are reddish grits, which Professor Robb regards as a repetition of those at Bathurst, so that we have at Buctouche an anticlinal bringing up the lower members of the Carboniferous series. From Buctouche to Shediac the dips are southerly. Shediac Harbour seems to be near the centre of another flat synclinal, and thence to Cape Tormentin the beds dip to the N.E. at small angles. Cape Tormentin appears to be in the axis of an anticlinal form, extending inland toward the wide Lower Carboniferous area of Albert county, but on the coast not bringing up anything older than the lower part of the Coal formation. The end of this undulation, at the extremity of Cape Tormentin, is covered by a small

patch of micaceous red sandstone, which appears to be an outlier of the New Red Sandstone of Prince Edward Island. Bay Verte presents another slight synclinal undulation, continuous apparently with that which appears at Dorchester Ferry; and south of this is the anticlinal which brings up the Lower Carboniferous limestones of Northern Cumberland, and which limits the coal trough of the Joggins in Nova Scotia.

The coast section above described, as given in Professor Robb's manuscripts, is included in the general section attached to the map, to which the reader is referred.

It would appear from this section, compared with those farther inland, as, for example, in the vicinity of Frederickton, that in the northern and western part of the New Brunswick coal area the Lower Carboniferous Formation is little developed, except in the form of grits and conglomerates; and that the greatest development of the calcareous members of the Lower Carboniferous and of the Lower Carboniferous Coal measures occurs in the southern part of the area, the principal exception being the occurrence of limestone and gypsum in the Tobique outlier. The same deficiency occurs in Nova Scotia on the northern side of the Cobequid Hills.

In the next place, in so far as ascertained, the Coal formation proper appears in New Brunswick to have a less thickness than in Nova Scotia, and to include only two principal coal groups—one near the base, and the other near the summit. To the former, I refer the coals of the coast near Bathurst, of Richebucto, and of the vicinity of Frederickton, unless, indeed, the upper members of the series there overlap and conceal the lower; to the latter, those of Miramichi, and possibly those of Cocagne and Grand Lake. This would accord also with such evidence as fossils afford, since, as I have elsewhere shown,* the plants of the Coal measures near Bathurst have a Lower Coal formation aspect; those of Grand Lake are more akin to those of the Upper Coal formation.

On the one hand, the great uniformity of the New Brunswick area, so far as observed, would lead to the belief that these exposures represent fairly its available resources of coal, which, in that case, are great as to area, but insignificant as to thickness, and consequently as to productive value. On the other hand, it is quite possible, judging from the analogy of other countries, that there may be portions of this area as yet unexplored, in which mineral fuel may have been more bountifully produced. Farther, as the Grand Lake beds seem to belong to the Upper series, and borings already made would indicate that the Lower series may be reached there, it would be desirable that

* "Synopsis of the Carboniferous Flora."

effectual measures should be taken to ascertain their actual value, either by boring or by searching for their outcrops, and also that the Grand Lake beds themselves should be proved in their extension both east and west. In Nova Scotia very remarkable changes of thickness occur in the coal-beds in tracing them from one locality to another; and though this is perhaps less likely in New Brunswick, yet it is quite possible that more valuable beds than any yet known may exist, more especially in the central part of the area, where the great flatness of the beds and their general covering with soil and forest have prevented any effective exploration.

I have not had an opportunity of visiting the coal mines at Grand Lake; but, from a paper read by Mr Matthew before the Natural History Society of New Brunswick, it appears that mining is prosecuted at two places,—Coal Ridge and Coal Creek. At the former place the coal is found in a bed nineteen inches in thickness. At the latter the thickness is only seventeen inches—the distance between the two localities being three and a half miles. Only one bed appears to have been discovered. The dip of the coal is to the southward at a very small angle.

Mr Matthew states, in addition to the considerations above mentioned, the very important fact, that older slates are found cropping out to the surface about ten miles from the mouth of Coal Creek. This would indicate, as he states, that the Coal measures may be very shallow at this place. It gives, however, a probability that the coal-beds may vary in productiveness on different sides of such an island of older rocks, as is observed to be the case in Nova Scotia. In other words, if the New Brunswick coal area is traversed by buried ridges of older rocks, these may divide it into subordinate areas of deposit, some of which may be much more valuable than others.

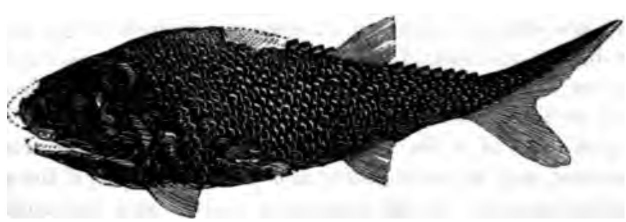
In conclusion, I would venture to express the opinion that the question as to the actual value of the coal area of New Brunswick can be settled only by the slow progress of accidental discovery, or by boring operations undertaken in those places where the upper series of coal-beds makes its appearance; and that the analogy of the Nova Scotia coal regions would indicate that the probability of the occurrence of large beds will be greatest along the southern side of the coal area, and where the Coal measures approach most closely to the older rocks. Of course, it would be useless to bore so near to these last that only the lower part of the Carboniferous series would be penetrated. It is where indisputable indications exist of the presence of the upper portion of the Coal measures that such trials should be made; and the best scientific advice as to locality should be secured before entering on expensive operations.

2. *The Lower Carboniferous Coal Formation in New Brunswick.*

This remarkable group of rocks, which does not appear, so far as known, in the coal area of Cumberland, though it is developed in other parts of Nova Scotia, appears in New Brunswick to be of considerable thickness, and can be traced from the neighbourhood of Dorchester for some distance along the north side of the coast range of metamorphic hills. It is characterized by the same species of fossil plants as at Horton Bluff in Nova Scotia, and, like the beds at that place, these are rich in remains of fishes. They differ, however, from the rocks of similar age in Nova Scotia by the remarkable development of highly bituminous shales in connexion with considerable deposits of an asphaltic mineral, to which the name "Albertite" has been given, and which is highly valued as a material for the manufacture of coal oil and illuminating gas. I examined these deposits in 1852, in the company of Sir Charles Lyell, and shall first give, without any material alteration, the account of the locality as I then saw it, and as it was described in the first edition of this work, adding a summary of more recent observations, and the new conclusions to which they lead.

Albert Mine, Hillsborough.—The beds at this place are thin-bedded shales, composed of extremely fine indurated clay with much bituminous matter. Some of them contain much lime, and when this is dissolved away by the weather or by an acid, the bituminous matter remains in the form of light porous flakes, resembling half-decayed bark. These shales contain great numbers of fossil fishes in a remarkably perfect state. They are flattened by pressure; but their forms are perfectly preserved, and the fins are as perfect as they were in life. They belong to the genus *Palæoniscus*, and are probably identical with some of those in the Coal formation of Nova Scotia (Fig. 62),

Fig. 62.—*Palæoniscus Alberti* (?)—Jackson.



but they have been buried in such a manner that every scale is in its place, instead of being scattered about, as at the Joggins and in the

Carboniferous rocks generally. The shales containing these fossils have been singularly disturbed and contorted, and they contain a vein of a remarkably pure and beautiful bituminous substance, allied to pitch-coal, and of great value as a material for gas-making. This substance unfortunately became a subject of litigation; and as one point in dispute was whether it should be called coal or asphaltum, scientific gentlemen were summoned from the United States as witnesses, and the most discordant opinions were given, both as to the name of the mineral and its geological age. This was not wonderful in the circumstances, for the substance was really a new material, intermediate between the most bituminous coals and the asphalts, and the geologists examined had enjoyed very few opportunities of studying that very remarkable group of Lower Carboniferous rocks to which the deposit belongs. Consequently some, in all sincerity, called the mineral coal, others asphalt; and some maintained that it was in the true Coal formation, while others believed it to be in the Old Red Sandstone. Only one of the geologists employed, Dr Percival of New Haven, assigned the deposit to its true geological position, as subsequently ascertained by Sir Charles Lyell and the writer, and stated above. To give an idea of this singular deposit, I quote the following details from a paper contributed by me to the Geological Society of London:—

"The pit for the extraction of the mineral is situated on the south side of Frederick's Brook, a small stream running eastwardly into the Petitcodiac, and near the junction of two branches of the brook. In approaching the mine from the south, the shales are seen in nearly a horizontal position in a road-cutting. This may be a deceptive appearance. Dr Percival, however, considers it the true arrangement at this point. At the pit-mouth the beds dip to the south at angles of 50° and 60°, and consist of gray and dark-coloured thin-bedded bituminous shales; and these shales appear with similar dips on the south branch of the brook. The outcrop of the coal is not now seen, but in a line with it I observed a remarkable crumpling and arching of the beds in the bank of the brook, at the point where the southwardly dipping beds above noticed meet a similar or the same series dipping to the north-west; this is represented in Fig 63. The outcrop of the coal in the bed of the brook was, as I was informed, very narrow, and the appearances now presented are as if the shales had arched over it. On the northern side of the arch above referred to, and in the north branch of the brook, are seen a thick series of bituminous and calcareous shales, with three beds of sandstone, the whole dipping to the north-west at a high angle. The strike of

one of the most regular beds I found to be S. 18° W. magnetic. Many of the shales contain scales of fish, and one of them has a

Fig. 63.—*Arched Strata, near Albert Mine.*

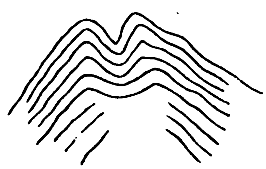
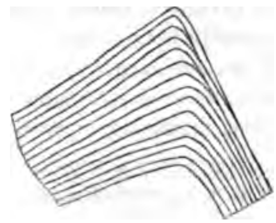


Fig. 64.—*Bent Strata, near Albert Mine.*



peculiar oolitic structure, consisting of a laminated basis of impure coaly matter or earthy bitumen, with crystalline calcareous grains, which are removed by weathering, and leave a light vesicular inflammable residuum of very singular aspect. The shales are in some places remarkably bent and contorted, as if by lateral pressure when in a soft state. A part of one of these flexures is accurately represented in Fig. 64, and illustrates some appearances in the mine to be subsequently noticed.

"The principal shaft has been sunk perpendicularly from the outcrop of the coal, and at its bottom is sixty-seven feet south of it. The gallery connecting the bottom of the shaft with the coal shows thin-bedded bituminous shales with calcareous and ironstone bands and concretions, dipping at the end nearest the coal S.S.W., at an angle of 60°, though a dip to the S.E. is more prevalent along this side of the mine. The coal at this place is about ten feet in thickness, and its upper surface dips N.W. about 75°. On the S.E., or under side, it rests against the edges of the somewhat contorted beds already noticed as dipping to the southward, and on the north-west side it is overlaid by similar beds dipping in the same direction with the coal, but so much contorted as to present on the small scale a most complicated and confused appearance. The coal itself, as seen in mass underground, presents a beautiful and singular appearance. It has a splendent resinous lustre and perfect conchoidal fracture; it is perfectly free from mineral charcoal and lines of impure coal or earthy matter. It is, however, divided into prismatic pieces by a great number of smooth divisional planes, proceeding from wall to wall, much in the manner of the cross structure seen in carbonized trees, and in the streaks of pitch-coal in the ordinary coals. At the N.W. side or roof, the coal joins the rock without change. On the S.E. side, on the contrary, there is a portion of coal a few inches thick,

including angular fragments of the shale, some beds of which on this side are very tender and cleave readily into rhomboidal pieces. The coal enveloping these fragments must have been softened sufficiently to allow them to penetrate it, but it has more numerous and less regular divisional planes than in the central parts of the mass, and has probably been shifted or crushed somewhat, either when it received the included fragments or subsequently. Both at the roof and floor, the coal shows distinct evidence of a former pasty or fluid condition, in having injected a pure coaly substance into the most minute fissures of the containing rocks. On both roof and floor also, but especially the latter, there are abundant evidences of shifting and disturbances in the slickenside surfaces with which they abound. All these appearances I have endeavoured to represent in Fig. 65, which agrees in the essential points with a similar figure given by Professor Taylor, who does not, however, represent the contorted state of the beds and the crushing of the lower side of the coal.

Fig. 65.—*Relation of the "Albert Coal" to the containing beds, as seen near the shaft of the mine.*

"The levels of the mine extend on both sides of the shaft along the course of the coal. On the south-west they extend about 170 feet, when the coal narrows to a thickness of one foot. In this direction, however, I had not time to examine them. In proceeding to the N.E., the coal has a general course of N. 50° E., bending gradually to N. 65° E., and everywhere presenting the appearances already noticed, though attaining, in one place, a width of thirteen feet. At the distance of about 200 feet from the shaft, a remarkable disturbance occurs. The main body of the coal bends suddenly to the northward, its course becoming N. 29° E.* for about twenty-five feet, when it returns to a course of N. 50° E. At the bend to the northward, a small part of the vein proceeds in its original course, and is stated by the persons connected with the mine to run out, leaving a large irregular promontory of rock between it and the main body of the coal. This disturbance has been variously represented as a fault, and as a cutting of the vein across the strata. Though I confess that the appearances are of a puzzling character, and are but imperfectly exposed in the mine, the impression left on my mind is, that it is, on a large scale, a flexure

* These measurements were made with a pocket prismatic compass. They differ slightly from those of Dr Jackson, either from accidental circumstances, or from being taken in different levels of the mine.

similar to that represented in Fig. 64, and accompanied by a partial tearing asunder of the beds. It seems evident that the beds must have been in a soft state at the time when this disturbance occurred, although there may have been subsequently some vertical shifting, especially on the west side of this 'Jog.'

"Beyond this flexure, the deposit contracts in width, and becomes more regular, and eventually its containing walls assume a conformable dip to the S. 5° E., at an angle of 69°. The appearance presented at the time of my visit in the extreme end of the most advanced level, is represented in Fig. 66, where it will be observed that the S.E. wall still shows indications of the prevailing contortions of the beds, and of the manner in which these cause the ends of strata to abut against the coal.

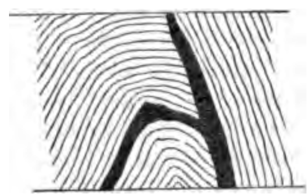
Fig. 66.—*Section of the beds at the East end of Albert Mine.*

"At this place, an exploratory level, driven to the S.E., shows a series of bituminous shales, with bands of ironstone, dipping regularly to the south-eastward. I could not, in any part of the mine, find beds corresponding to the Stigmaria underclay of ordinary coal-seams, though on the S.E. side some of the beds are of a more compact and purely argillaceous character than those on the N.W. side or roof of the seam. The ironstone bands and fish-bearing shales are, however, not very dissimilar from those in some Coal measures of the ordinary Coal formation. They present no indications of metamorphism or of the passage of heated vapours, and all their appearances show that their bituminous matter has resulted from the presence of organic substances at the time of their deposition.

"It is evident that all the above phenomena can be explained on the supposition that this coaly mass occupies a fissure running along an anticlinal bend of the strata; and that, apart from the character of the mineral and the containing beds, this would be the most natural explanation. On the other hand, when we consider the contorted condition of the beds, indicating disturbance when in a soft state, and the slickenside joints, pointing to subsequent shifts, we cannot refuse to admit that a conformable bed of true coal, if subjected before and after its consolidation to such movements, might present all the appearances of complication and disturbance observed in this mass, more especially if originally of small extent, and thinning out toward the edges. On this view we should have to suppose,—(1.) Disturbance and contortion of the beds while soft, and, at the point in question, a regular and somewhat abrupt arching of the beds; (2.) A fault throwing

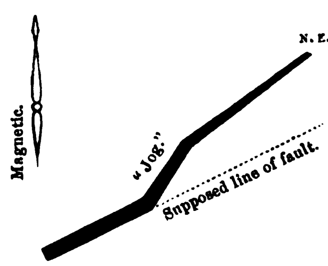
down the south side of the arch along a line coinciding in part of its course with the highly inclined underside of the coal at the north side of the arch; and (3.) Removal of the upper part of the north side of the arch by denudation. Fig. 67 represents the appearances which would thus be produced, and it will be seen that they very closely correspond with the present condition of the deposit, not excepting its thinning toward the surface. If this be the true explanation, it is probable that the sunken south side of the bed has not yet been reached in the excavations. It might, however, in approaching it from above, show a succession of wedge-shaped included masses of rock or "horses," one of which I saw in the floor of the lowest level. On this view, also, the 'Jog' or fault above described may be a lateral bend received by the bed in the original contortion of the strata; and at this point the straight fracture, producing the supposed downthrow, may have left the bed, and thus caused the appearance of the vein running in the former course of the bed along the line of fault, and also the greater regularity of the bed beyond the 'Jog.' This explanation is represented in Fig. 68."

Fig. 67.—*Ideal representation of the Cause of the appearances at Albert Mine.*



As many readers of this work may be interested in the controversies respecting this mineral, I may shortly mention its physical and chemical properties, and the results at which I have arrived respecting its nature and origin.

Fig. 68.—*The "Jog" at Albert Mine, and its supposed relation to the line of fault.*



The substance has externally an appearance not dissimilar from the ordinary asphalt of commerce in its purest forms; but it is very much less fusible, and differs in chemical composition. Its fracture is conchoidal. Its lustre resinous and splendent or shining. Its colour and the powder and streak on porcelain, black; and it is perfectly opaque. It is very brittle and disposed to fly into fragments. Its hardness is 3, nearly, of Mohs' scale. Its specific gravity is 1·08 to 1·11 (according to Jackson and Hayes). It emits a bituminous odour, and when rubbed becomes electric. In the flame of a spirit-lamp it intumesces and emits jets of

gas, but does not melt like asphalt. In a close tube, however, it can be melted with some intumescence. In the above characters, with the exception of the colour of the powder, it agrees more nearly with the finer varieties of *Jet* or *Pitch-Coal*, than with any other substance. For this reason I made comparative trials of its composition and that of specimens of jet from Whitby, with the following results:—

	Albert Mineral.	Whitby Jet.
Water	·4	1·5
Volatile combustible matter .	57·2	57·1
Coke	42·4	41·4
	100·0	100·0
Ash in coke	·27	4·0

These results indicate a remarkable similarity in the proportion of volatile and fixed combustible matter; an ultimate analysis might, however, establish important differences of detail.

If we compare the "*Albertite*," as it has been named by persons desirous of not committing themselves, with the substances most nearly allied to it, we can scarcely avoid arriving at the following conclusions:—In its behaviour in the fire, chemical composition, and electrical properties, the substance is nearly allied to jet, from which, however, it differs in its extreme brittleness, its greater uniformity of texture, and more perfect lustre and fracture, and also in its black streak: a character which also separates it from ordinary bituminous coal and all the varieties of asphaltum. Its nearest analogue in this last particular is Lesmahagow cannel. Its lustre and fracture remarkably assimilate it to the finer varieties of asphalt, but its streak, mode of combustion, and chemical composition, effectually separate it from them. On the whole, the above considerations, in connexion with a number of experiments made by Jackson, Hayes, and others, and published in the Reports on the mineral, place the substance at the head of the *Pitch Coals* or Jets, as the purest variety of that species of bituminous coal. It has, however, some claims to be viewed as a distinct mineral species, intermediate between coals and asphalts; and I suspect that its chemical composition may approach to that of *Asphaltene*, the coaly ingredient of the Asphalts.

Under the microscope, I have not been able to detect any organic structure, though I have found in some slices cells filled with yellow resinous matter, similar to those that occur in cannel-coal. Mr Bacon of Boston, however, states (in Jackson's Report), that he has found traces of cellular tissue; but Professor Quekett of London, after examining many specimens, considers it destitute of organic structure.

Some specimens of the mineral are laminated, and have brilliant discs about a line in diameter on the surfaces of the laminæ. Under the microscope, these discs exhibit very fine concentric and radiating lines, but they are merely concretionary, and in Pictou coal such discs sometimes occur in an oblique position as regards the lamination. The Albertite has been declared to be free from sulphur; but minute concretions of ironstone and iron pyrites occur in it, and films of iron pyrites line some of the fissures of the containing beds. These appearances are, however, rare.

In inquiring into the origin and mode of formation of the deposit, the following alternatives present themselves:—(1.) It may have been a bed or sheet of bituminous matter, thinning out at the edges, like that in Kent, U.C., described in the Report of the Canadian Survey for 1851–2,* and probably produced by the oxidation and hardening of the liquid produce of naphtha-springs. (2.) It may be bituminous matter melted by internal heat or fluid at ordinary temperatures, like petroleum, and poured into an open fissure, and subsequently consolidated, as was perhaps the case with the *chapapote* of Cuba.† (3.) It may, like jet and other coals, have resulted from the bituminization of woody matter. With respect to these several hypotheses, I can merely state the probabilities which occur to me from the facts already known, and which may of course be greatly modified by the more perfect exploration of the deposit.

On the first of these hypotheses, though there is no great improbability in supposing the deposit to have been a conformable bed, it does not seem likely that so large and extremely pure a mass of bituminous matter could be a deposit from springs, or that, without alteration of the containing beds, it could have assumed an aspect and consistence so much akin to those of coal. It also seems difficult on this view to account for the deposition, in waters tenanted by fish, of the accompanying laminated bituminous shales.

The second view requires us to suppose that, after the crumpling and contortion of the beds, and the production of an open fissure, an underlying portion of the bituminous shales was exposed to heat and pressure, which caused its bituminous ingredient to be melted, forced upward, and consolidated in the upper and unaltered portion of the beds, or that the more liquid bituminous matter naturally oozed out of the containing rocks. This would account for the occurrence and most of the appearances of the coaly deposit; but we must of course still suppose that the bituminous matter was originally produced during the deposition of the shales, probably from organic matter.

* Page 90. † Taylor, Statistics of Coal.

Some countenance is given to this view by the existence of petroleum springs at present in the continuation of the same deposit, and by the presence of minute fissures filled with the mineral, which might, however, be explained on the supposition of pressure exerted on a soft or semifluid bed.

The hypothesis of formation from woody matter, after the manner of coal, is also accompanied with serious difficulties. The composition of jet and of recent bituminous coal found in peat-bogs, prove the possibility of this mode of formation; and this is certainly the most natural way of accounting for the production of the coaly and bituminous matter of the containing beds; but large and pure beds of coal are usually accompanied by evidences of growth *in situ*, and accumulations of drift-trunks are usually loaded with earthy matter, while none of these conditions exist in the deposit in question. The want of the first is, however, perfectly consistent with the long and perfect decomposition implied in this view, as well as in the homogeneity of the mass, and the abundance of bitumen in the containing shales; and in a deposit containing so little evidence of strong currents or violent changes, it may not be unreasonable to suppose that drift vegetable matter may have accumulated during long periods in clear water. In connexion with this it is worthy of remark, that the comparative absence of iron pyrites, in connexion with the presence of large quantities of carbonate of iron in the shales, *proves** that these beds were deposited in fresh and very pure water, if it be admitted that their bitumen resulted from the decomposition of organic matter. Neither is the great purity of the mineral an evidence against its accumulation in the manner of ordinary coal, since varieties of coal almost equally pure have long been known.† On this view, then, which is perhaps the most probable of the three, the Albert deposit is a fresh-water formation of a very peculiar character, belonging to the Lower Carboniferous period, and very singularly *distorted by mechanical disturbances.*

The above was the impression on my mind in 1855 as to the origin of the Albertite. Now, in 1867, I confess that it is somewhat modified. The subsequent explorations of the deposit have given to it more unmistakably the aspect of a vein or fissure. The remarkable veins of altered asphalt which I have seen in the rocks of the Quebec group at Point Leir, have afforded a parallel case more distinct in its character. All the more recent explorers who have visited the

* See paper by the writer on the "Colouring Matter of Red Sandstones," in Proceedings of Geological Society.

† See Assays in Taylor's Statistics of Coal.

locality—Hitchcock, Bailey, and Hind more especially—have adopted the theory of a vein filled with bituminous matter. I regard therefore this mode of occurrence, or the second of those above mentioned, as established, and it only remains to consider whence the supplies of liquid bitumen could have been obtained. I have no hesitation in assigning them to the highly bituminous Lower Carboniferous shales. These beds are manifestly of the same character with the so-called "oil coals" of Nova Scotia, and the earthy bitumens of Scotland. They must have been beds of mud charged with a great quantity of finely comminuted vegetable matter, of the nature of peaty muck, which has become perfectly bituminized, and which probably in an earlier stage of its formation was more prone to ooze into fissures as a liquid petroleum than at present. The deposit of the Albert Mine would thus be a vein or fissure constituting an ancient reservoir of petroleum, which, by the loss of its more volatile parts and partial oxidation, has been hardened into a coaly substance; and the examples of similar phenomena which I have seen in Canada induce me to believe that the agency of internal heat would not be required to produce the observed result. It is true that one able observer has supposed that the supplies of petroleum from which the Albertite has been formed, have been afforded by the underlying Devonian beds; but no evidence exists of the occurrence of bituminous matter in these rocks in New Brunswick. The peculiar Corniferous limestone which is the reservoir of petroleum in Canada, does not occur in New Brunswick, and the Lower Carboniferous shales themselves contain abundance of the material required. In this view, though the Albert shales are Lower Carboniferous, the vein of Albertite must have been formed at a later period, after the beds had begun to experience disturbance. In this as in other respects the deposit of this curious mineral differs remarkably from ordinary coal, which always constitutes conformable beds contemporaneous with the enclosing strata.

With regard to the original formation of the shales, their lamination and their great thickness, as well as the nature of their material, show that their formation was gradual, and probably occupied a long period. I do not regard the state of preservation of the fishes as any objection to this. They may have been killed by occasional eruptions of mud loaded with organic matter rendering the water unwholesome. When once embedded in mud of this character, their parts could not be separated, and even their soft tissues might be preserved, as in modern peat, for a long time. The swarms of cyprids which devoured dead fishes in other parts of the Carboniferous areas do not seem to have been present. Farther, though in some layers the fishes occur in a

perfect state of preservation, in the greater part of the deposit they are found to be represented only by scattered scales. On the supposition that the shales themselves represent what may be called vegetable mud, this may have accumulated in water at times sufficiently pure to be inhabited by fishes, while at other times streams or inundations of muddy water may have caused the destruction of the fish in certain localities. The conditions may in this way be compared to those represented by the calcareo-bituminous shales at the Joggins. The best exposure that I have seen of the Albert shales is on the Memramcook River, where they present a continuous cliff for some distance, exhibiting beds of brownish and black very pure grained shale, all highly bituminous, though of various degrees of richness. The stratification is apparently arched, the crown of the arch being capped with conglomerate, in which are slender asphaltic veins. The thickness of shales observed at this place was estimated at 150 feet.

Westward of the Albert Mine, it would seem, according to Professor Bailey, that two or more bands of calcareo-bituminous shale extend along the base of the metamorphic hills, or possibly there may be repetition of the Albert shales by folds along parallel lines. Professor Bailey mentions their occurrence at Baltimore, six miles west of Albert Mine, also at Elgin and Pollet River. At the former place, fish-teeth of the Rhizodont type and *Lepidodendron corrugatum* were found by Mr Hartt, giving the character of the fossils here a very strong resemblance to those of Horton Bluff. Still farther westward, the shales occur at Sussex, at Trout Creek, and, lastly, at Norton, fifty miles westward of the Albert Mine. In these more western localities, however, the Albertite has not been found in workable quantities. Springs yielding petroleum flow from these rocks in various places, and attempts have been made to obtain the substance in profitable quantities, but hitherto, I believe, without any encouraging amount of success.

3. *Fossils of the Carboniferous District of New Brunswick.*

I give here merely a list of the plants determined by myself, principally from the collections of Mr G. F. Matthews, Mr C. F. Hartt, and Sir William E. Logan, with a few animal fossils noticed by Mr Hartt in the Appendix to Bailey's Report on New Brunswick. It will be observed, in connexion with the previous statements, that the plants from Bathurst and Baie de Chaleur are supposed to belong to the lower set of coal-beds in the Middle Coal measures; those from Grand Lake and Miramichi to the upper set of beds.

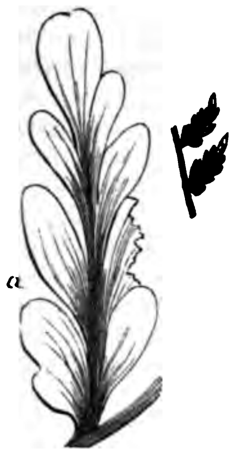
FOSSIL PLANTS.

(*a*) *Middle and Upper Coal Formations.*

Dadoxylon materiarium, *Dawson*, Miramichi.
Dadoxylon Acadianum, *Dawson*, Dorchester.
Calamodendron approximatum, *Brongnt*, Coal Creek, Grand Lake.
Antholites rhabdocarpi, *Dawson*, „ „ „ „
Calamites Suckowii, *Brongnt*, Coal Creek, Grand Lake; Gardner's Creek.
C. Cistii, *Brongnt*, Coal Creek, Grand Lake; Baie de Chaleur.
C. nodosus, *Schlot.* „ „ „ „
C. cannæformis, *Brongnt*, Gardner's Creek.
Asterophyllites grandis, *Sternberg*, Coal Creek, Grand Lake; Baie de Chaleur.
Annularia sphenophylloïdes, *Zenker*, Coal Creek, Grand Lake; Baie de Chaleur.
Sphenophyllum emarginatum, *Brongnt*, Coal Creek, Grand Lake; Baie de Chaleur.
S. saxifragifolium, *Sternberg*, Baie de Chaleur.
Cyclopteris (Nephropteris) obliqua, *Brongnt*, Coal Creek, Grand Lake.
C. (? Neuropteris) ingens, *L. & H.*
Neuropteris rarinervis, *Bunbury*, Coal Creek, Grand Lake; Baie de Chaleur.
N. gigantea, *Sternberg*, Coal Creek, Grand Lake.
N. Loshii, *Brongnt*, Gardner's Creek? Baie de Chaleur.
N. auriculata, *Brt.* „ „
Odontopteris Schlotheimii, *Brongnt*, Baie de Chaleur.
Sphenopteris munda, *Dawson*, Coal Creek, Grand Lake (Fig. 69).*
S. latior, *Dawson*, „ „ „ „ (Fig. 70).
S. gracilis, *Brongnt*, „ „ „ „
S. artemisifolia, *Brongnt*, „ „ „ „
S. Canadensis, *Dawson*, Baie de Chaleur (Fig. 71).
S. obtusiloba? *Brongnt*, „ „
Alethopteris lonchitica, *Sternberg*, Coal Creek, Grand Lake.
A. nervosa, *Brongnt*, Baie de Chaleur.
A. muricata, *Brongnt*, Bathurst.
A. pteroides, *Brongnt*, „
A. Serlii, *Brongnt*, Baie de Chaleur.
A. grandis, *Dawson*, „ (Fig. 72).
Beinertia Gœpperti, *Dawson*, Coal Creek, Grand Lake; Baie de Chaleur.

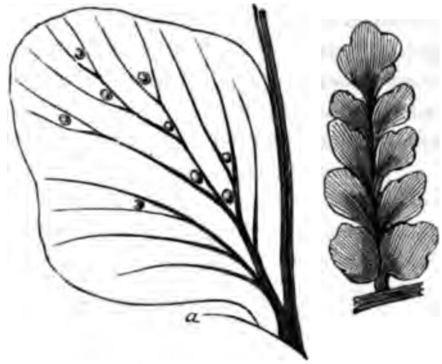
* Figs. 69 to 73 represent some interesting ferns and a Nœggerathia characteristic of or peculiar to the Coal Formation of New Brunswick.

Fig. 69. — *Sphenopteris munda.*



(*a*) Pinnule magnified.

Fig. 70.—*Sphenopteris latior.*

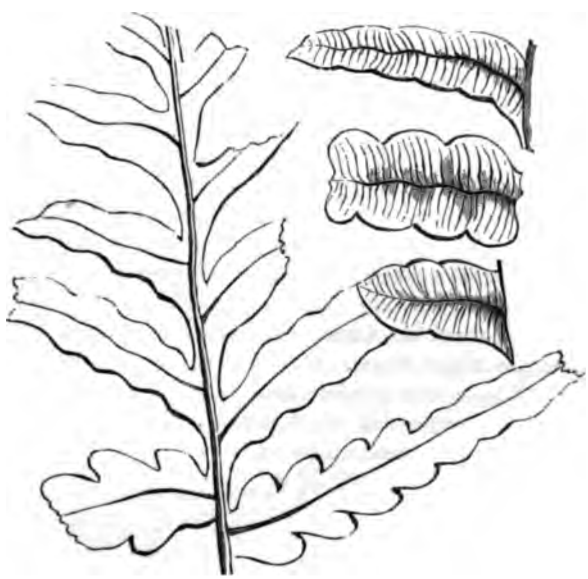


(*a*) Pinnule magnified.

Fig. 71.—*Sphenopteris Canadensis.*

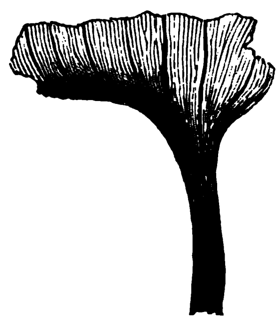
(*a*) Pinnule magnified.

Fig. 72.—*Alethopteris grandis.*



Palæopteris Harttii, *Dawson*,	Coal Creek,	Grand Lake.	
Lepidodendron Pictoense, *Dawson*,	,,	Newcastle River,	Grand Lake.
Lepidostrobus squamosus, *Dawson*,	,,	,,	,,
Cordaites borassifolia, *Corda*,	,,	,,	,,
C. simplex, *Dawson*,	,,	Baie de Chaleur.	
Cardiocarpum bisectatum, *Dawson*,	,,	Newcastle River,	,,

Fig. 73.—*Nœggerathia dispar. Half nat. size.*



Nœggerathia dispar (Fig. 73), *Dawson*, Baie de Chaleur.
Halonia? sp.? *Dawson*, Coal Creek.

(*b*) *Lower Coal Formation—(Horizon of the Albert shales, etc.).*

Cyclopteris Acadica, Dawson, Norton Creek.
Lepidodendron corrugatum, * ,, ,,
Cordaites borassifolia Corda, Albert shales. (Figured in Jackson's Report.)

FOSSIL ANIMALS.

Mr Hartt mentions (Appendix to Bailey's Report) that the only animal fossils he has found in the Coal measures are *Spirorbis carbonarius*, attached to plants, and coprolites of fishes. In the Lower Carboniferous Limestones he has observed fossils of most of the genera to be noticed in subsequent pages as occurring in these beds in Nova Scotia; but they have not been examined as to species, which, however, in so far as my observation extends, are identical with those of Nova Scotia. Dr Jackson has named and figured three species of *Palæoniscus* from the Albert shales. One of these is represented in Fig. 62 above; and I have seen another specimen which appears to belong to a second of this species, but the figures and descriptions are not sufficient for their certain determination.

* See Figs. 74, 75, and 76 below.

4. *Useful Minerals of the Carboniferous District of New Brunswick.*

The information under this head has been kindly communicated to me by Professor Bailey, of King's College, Frederickton.

Bituminous Coal.—Though covering so large a surface area, or more than two-thirds of the entire extent of the province, the Carboniferous or coal-bearing rocks of New Brunswick have afforded as yet but little promise of large or valuable deposits of this most important product. With the single exception of the beds at Grand Lake in Queen's County, which are but 22 inches in thickness, no stratum of bituminous coal, sufficiently large or pure to be profitably worked, has yet been discovered. Nor can the prospects of future discoveries be regarded as very encouraging. The following are the more important facts from which this conclusion may be drawn :—

1st, The strata of the New Brunswick Coal-field are nowhere greatly disturbed, the beds being nearly horizontal and continuous over wide areas. Borings or other explorations therefore at various points afford an approximately accurate idea of the whole district. Such borings, undertaken at Grand Lake in 1837, affirmed the existence, at the depth of about 250 feet, of a second bed of "bituminous shale and coal," eight feet in thickness; but as prominence is given to the shale, and the relative proportion of each not stated, the observation is of little value. Similar borings have more recently been made on the Cocagne River in Kent County, where the formations resemble those of Grand Lake, to a depth of 410 feet. Several small seams of coal were passed through, the largest of which was about 31 inches (or more correctly 19 inches and 12 inches, with 12 inches of freestone intervening),* but the results were not such as to justify farther exploration.

2d, The whole formation, though of great superficial extent, has apparently but slight thickness. This is evidenced in two ways: *1st*, By the fossils of the associated beds, which, according to Professor Dawson, indicate the admixture of the floras of several different horizons; and, *2dly*, By the fact that in the Grand Lake district, as shown by Mr C. R. Matthews, the rocks of the Coal measures are penetrated by those of the older metamorphic formations upon which they rest. With strata nearly horizontal in position, and having apparently but slight thickness, the borings already made give little promise of future discoveries of great value.

To these general conclusions, however, it is but right to add, that

* For this information I am indebted to Mr Edward Allison of St John, by whom these explorations were undertaken.

but a small proportion of the entire coal-field has been made the subject of accurate examinations, and these, for the most part, have been confined to its central and southern portions. The eastern coast region, and certain detached areas near the Bay of Fundy, may yet prove more productive than the regions hitherto examined. It follows, moreover, from the nearly horizontal character of the formation, that such beds as do exist may have a wide lateral extension, and if at a moderate depth, may be removed, as is done at Grand Lake, at a comparatively trifling coast.

The coal of Grand Lake, as well as of all the other outcrops yet observed in the true Carboniferous formation, is the ordinary bituminous or caking coal, capable of ready ignition, but requiring frequent stirring for complete combustion. While not so well adapted for household use as the foreign imported coals, it has, from its comparative cheapness ($4 to $5 per ton in the market of St John), attained a local consumption of nearly 6000 chaldrons annually, and for manufacturing purposes is preferred to any of the imported coals. About 1000 tons of this coal were exported in the year 1865. It is capable of yielding 8500 cubic feet of gas per ton, but of inferior quality, and is not employed for this purpose.

The raising of this coal has heretofore been undertaken by many separate parties, and by a rude system of quarrying. It is now proposed to undertake operations of a more systematic kind, preceded by a preliminary boring, the results of which, it is hoped, will give a more accurate idea of the real value of the coal-field.

*Table of all known Out-crops of Bituminous Coal in the Province of New Brunswick equalling or exceeding five inches in thickness.**

County.	Locality.	Thickness. Ft.	Thickness. In.	Variety.	Quality.	Remarks.
York, ...	Nashwaak River,	0	5	Caking, . .	Fair, . .	Few bushels removed and burnt.
Queen's, . . .	Newcastle District,	1	8	Do. . .	Do. .	5000 chaldrons removed in 1864. 12,863 since 1828.
Do. . . .	Salmon River, .	1	10	Do. . .	Do. .	
Do. . . .	Coal Creek, . .	1	8	Do. . .	Do. .	
Do. . . .	Washademoak, .	1	0	Do. . .	Do. . .	Few bushels removed.
King's, . . .	"Dunsinane," . .	1	10	Bituminous,	Do. . .	Opened, not worked.
Albert, . . .	Cape Enrage, . .	0	8	Caking, . .	Do. . .	Not worked.
Kent, . . .	Cocagne River, .	2	0	Do. . .	?	
	Richibucto River,	1	8	Do. . .	Fair, . .	
Gloucester, .	New Bandon, . .	0	8	Do. . .	Do. . .	

* Extracted from Bailey's Report.

Table of all known Out-crops of workable Bituminous Shale and Asphaltum.

County.	Locality.	Thickness.	Variety.	Quality.	Remarks.
King's, . . .	Apohaqui, . . .	Irregular veins, . .	Albertite, .	Superior,	Not explored.
Do. . . .	S. Branch of the Kennebeckasis R.	...	Do. .	Do.	Not worked.
Do. . . .	Ward's Creek, .	...	Bituminous Shale, .	Fair, . .	Do.
Do. . . .	Dutch Valley, .	...	Do. .	Do. . .	Do.
Albert, . . .	Albert Mine, . .	1 inch to 17 feet, . .	Albertite, .	Superior,	Extensively worked.
Do. . . .	East Albert Mine,	...	Do. .	Do.	Now being opened.
Do. . . .	Baltimore, . . .	6 feet, . .	Bituminous Shale, .	Good, . .	Works erected but abandoned.
Do. . . .	Turtle Creek, . .	10 feet, . .	Do. .	Do. . .	Claims taken out.
Westmoreland,	Memramcook, . .	Large beds,	Do. .	Do. . .	Now being worked.

Quantity of Coal raised at Grand Lake since 1828.

1825,	...	66 Chaldrons.	1835,	...	3,537 Chaldrons.
1830,	...	70 "	1838,	...	2,143 "
1833,	...	138 "	1864,	...	5,000 "
1834,	...	687 "			

Total number of Chaldrons, 11,641.

Albertite.—This most valuable mineral is wholly confined to the rocks of the Lower Carboniferous Formation of King's, Albert, and Westmoreland Counties. It has at different times and by different authors been regarded as an asphalt, an asphaltic coal, a true coal, and a jet; but most authorities now agree in considering the substance as a variety of asphalt or a solid hydrocarbon, originally fluid, like petroleum, and derived from the decomposition of vegetable or animal products. The mode of occurrence of the mineral, and a discussion of the views concerning its origin, having already been given in a previous section, farther remarks in this connexion are deemed unnecessary.

From the original locality near Hillsborough, discovered in 1849, 56,289 tons have been exported in the three years, 1863 to 1865, paying during the same period to the Government a royalty of $8,089,29. The principal market for this coal is in the United States, where it is employed in the manufacture of oil and gas. Of the former, it is said to be capable of yielding 100 (crude) gallons per ton, while of the latter the yield is 14,500 cubic feet, of superior illuminating

power. In the latter case, where other coals are at the same time employed, there is left as a residuum a valuable coke.

Numerous attempts have been made to obtain Albertite from other localities than that above alluded to; but though the mineral has been found, and operations have been begun at several points, these latter have not as yet met with any marked success. The peculiar nature and origin of the substance, and the uncertainty attending all subjects relating to mineral carbons, may be one cause of this result. As, however, the accompanying and very characteristic shales have been traced over a wide extent of country, and have been observed to contain Albertite, though in small quantities, at points more than fifty miles remote from each other, it is reasonably hoped that other workable deposits will yet be found.

Bituminous Shales.—These, as above stated, occupy a wide extent of country, having been traced, in more or less parallel bands, from Apohaqui Station, near Sussex, to Dorchester, in the county of Westmoreland. The amount of bitumen contained in them is very various, that of the "Black Band" or richest bed at the Caledonia Works, in Albert, yielding 63 gallons of crude oil per ton, while those on the Memramcook, in Westmoreland, yield only 37. Numerous leases have been taken out within the last year for operations on these shales, both in Albert and Westmoreland, a company in the latter being about to erect 100 retorts, with the design of subjecting to distillation 100 tons of shale *per diem*. This is at present regarded as more profitable than to export the shale for distillation abroad, especially to the United States, where it would necessarily come into competition with the immense production of natural oils in that country. 1230 tons of shale were exported in the year 1865, of the value of $3075. The "Black Band" shales of Caledonia will yield 7500 cubic feet of gas per ton (about one-half of the quantity yielded by the Albertite), but leaves as a residuum a bulky and worthless ash.

Petroleum.—Springs containing an admixture of mineral oil or petroleum have been observed at several points in the Carboniferous districts, on the sides of the Petitcodiac River, in Albert and Westmoreland counties, and borings have been undertaken, but the amount of oil so far obtained has not proved sufficient to be remunerative. The latter is sometimes fluid, floating on the surface of the water; in other cases, hardened by exposure into a sort of mineral pitch termed "maltha."

Common Salt.—Saline springs, containing variable proportions of common salt, occur in the rocks of the Lower Carboniferous series, at a variety of points, and especially near Sussex, on the Salt Spring

Brook, in the parish of Upham in Westmoreland, and on the Tobique in Victoria. No beds of rock salt have been observed, nor is it known at what depth the saliferous strata may be found. Salt has long been made by the evaporation of the brines from Upham and Sussex, and is of excellent quality, but the works have heretofore been conducted upon a very limited scale.

Gypsum (Sulphate of Lime).—This is a very abundant mineral in New Brunswick, the deposits being numerous, large, and in general of great purity. They occur in all parts of the Lower Carboniferous district, in King's, Albert, Westmoreland, and Victoria, especially in the vicinity of Sussex, in Upham, on the North River in Westmoreland, at Martin Head on the Bay shore, on the Tobique River in cliffs over 100 feet high, and about the Albert Mines. At the last-named locality the mineral has been extensively quarried from beds about sixty feet in thickness, and calcined in large works at Hillsborough. 8646 barrels of plaster were exported in 1863, principally to the United States; but the trade has declined since the outbreak of the American war, and during the last year the buildings employed by the company were consumed by fire.

Anhydrite (Anhydrous Sulphate of Lime).—This mineral occurs with the last at Hillsborough, and the two are employed in connexion.

Alum.—This important substance frequently results spontaneously from the weathering of pyritous shales, and has been observed in small quantities at Grand Lake and elsewhere, resulting from these causes. As pyrites is abundant in the province, it may prove a source of the future supply of this substance. Alum was a few years ago manufactured in considerable quantities at Shepody Mountain, but the works have been abandoned, and are now in ruins.

Freestones are abundant in the Lower Carboniferous rocks of Albert and Westmoreland, and numerous quarries have been opened. They are of red, yellowish, and olive tints, often so soft as to be readily cut when freshly dug, but hardening on exposure, and are highly prized for building purposes, both in the province and in the United States.

Grindstones are found in the same quarries, and are of superior character. In 1864, 6814 tons of stone, including building and grindstones were exported from the province, while in 1860 the amount was over 13,000 tons.

Limestones are abundant in the Lower Carboniferous series, especially in the counties of King's, Queen's, Charlotte, St John, Albert, Victoria, and Westmoreland. The beds of this series are dark and more or less bituminous, yielding lime inferior to that of the older formations (*Laurentian* and *Silurian*) in St John and Char-

lotte counties, which afford the greater part of the lime used in the province.

Manganese.—Deposits of the peroxide of this metal, so largely employed in bleaching and glass manufacture, occur in the province at several points, especially at Bathurst, near Shepody Mountain, at Quaco, and Upham. At the latter locality, near the source of Hammond River, the deposit is large and of excellent quality, and considerable quantities are annually removed. 219 tons were exported in 1864 from the localities above mentioned. The ores occur, with the exception of that at Bathurst, in limestone near the base of the Lower Carboniferous system. Wad or black manganese ore is also abundant, but, while richer ores abound, is not of value.

CHAPTER XV.

THE CARBONIFEROUS SYSTEM—*Continued.*

CENTRAL CARBONIFEROUS DISTRICT OF NOVA SCOTIA AND ITS OUTLIERS—USEFUL MINERALS.

Carboniferous District of Colchester and Hants.

In this district, which is as extensive as that of Cumberland, from which it is separated by the Cobequid chain of hills, we have a very great development of the limestones and gypsums corresponding to the Napan and Pugwash rocks of Cumberland, and the Mountain or Lower Carboniferous limestone of England, and a very small development of the Coal measures. In other words, in the Carboniferous period marine deposits were formed to a greater extent and perhaps for a longer time on the south than on the north side of the Cobequid chain, which, we shall presently see, was then a ridge probably not so high, but perhaps nearly as continuous as at present.

On consulting the map, it will be seen that this district is very irregular in its form; partly because the modern bay, with its fringes of marsh and New Red Sandstone, penetrates into it, and partly because it in like manner penetrates in long inlets, now river valleys, into the older metamorphic hills to the eastward. Viewing this district, then, as a portion of the dried-up bed of the Carboniferous sea, its original shores can be observed both on the north and on the south. Thus on the flanks of the Cobequids, the Lowest Carboniferous beds consist of conglomerates; the stones and pebbles of which are identical with the rocks of the hills from which they have been derived, just as the materials of shingle beaches on modern coasts are derived from neighbouring cliffs. In like manner, at the base of the Horton and Ardoise Hills, the lowest beds consist of white sandstones composed of the debris of granite, and shales made up of the mud produced by the slow wasting of slate; both of these materials being furnished by the rocks of the hills. One difference, however, of a marked character occurs on these opposite shores. The material of the lowest rocks on the south side of the district is fine and almost destitute of pebbles;

that of the corresponding rocks on the north or Cobequid side is very coarse, being made up of large pebbles and even stones of considerable size. Similar differences occur in modern seas, and depend on the configuration and elevation of coasts, and their comparative exposure to the sea-swell and prevailing winds. The deposits in the more central part of the district are more uniform and persistent in their character.

In noticing this Carboniferous area, I shall describe, in the first place, some of the localities and sections in which the arrangement and character of its rocks are most distinctly exposed; and these will afford us opportunities of studying the Lower Carboniferous series, almost as perfect as those which we enjoyed at the Joggins in the case of the Coal formation deposits.

At Wolfville and Lower Horton, in the south-western part of the district, we find the Lower Carboniferous beds to consist of gray sandstones and dark shales, resting on the edges of the slates of the Gaspereau River. In the road-cuttings in Lower Horton, the sandstones may be seen to contain fine specimens of *Lepidodendron*, a genus of which we have already seen examples at the Joggins. There appear to be two or three species of this genus in the beds of Horton Bluff, and one of them at least is distinct from any of those found in the true Coal measures, and is most characteristic of this Lower Coal formation. It is the species which I have named *L. corrugatum* (Fig. 74), and is found on the same geological horizon as far west as Ohio. It is also closely allied to a characteristic species of this age in England and on the continent of Europe. With these *Lepidodendra* are found at Horton Bluff several other fossil plants, more especially the fine fern (Fig. 75), which I have named *Cyclopteris Acadica*, *Cordaites* (Fig. 76), *Stigmaria*, and the conifer *Dadoxylon antiquius*.

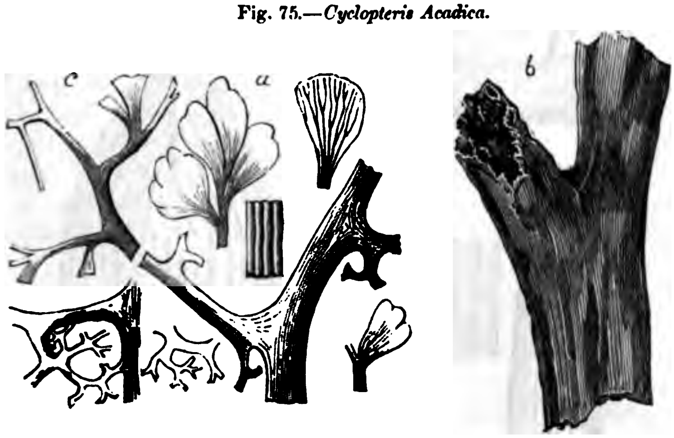
The *Cyclopteris Acadica* was a magnificent fern, unsurpassed by any in the Middle Coal formation. Its leaf-stalks are often two inches in diameter, and the frond, with its hundreds of wedge-shaped leaflets, must have been several feet in breadth. In some of the shales at the same locality fish-scales are extremely abundant, and make up apparently the greater part of the mass of some thin beds. The whole of these rocks are, however, much better seen at Horton Bluff, a fine range of cliffs extending along the west side of the Avon estuary. At this place the beds do not dip regularly in the same direction, but have been broken into great masses which dip in different ways, and have been fractured and displaced by *faults* or slips of one mass or another up or down, so as to break the continuity of the layers. Such disturbances are very frequent in all the sections of this district, and

it will be easily understood that in the upheaval of large surfaces of rock, these would readily give way along the lines of greatest and

Fig. 76.—*Fragment of Leaf of Cordaites.*

Fig. 74.—*Lepidodendron corrugatum —portion of bark.*

Fig. 75.—*Cyclopteris Acadica.*

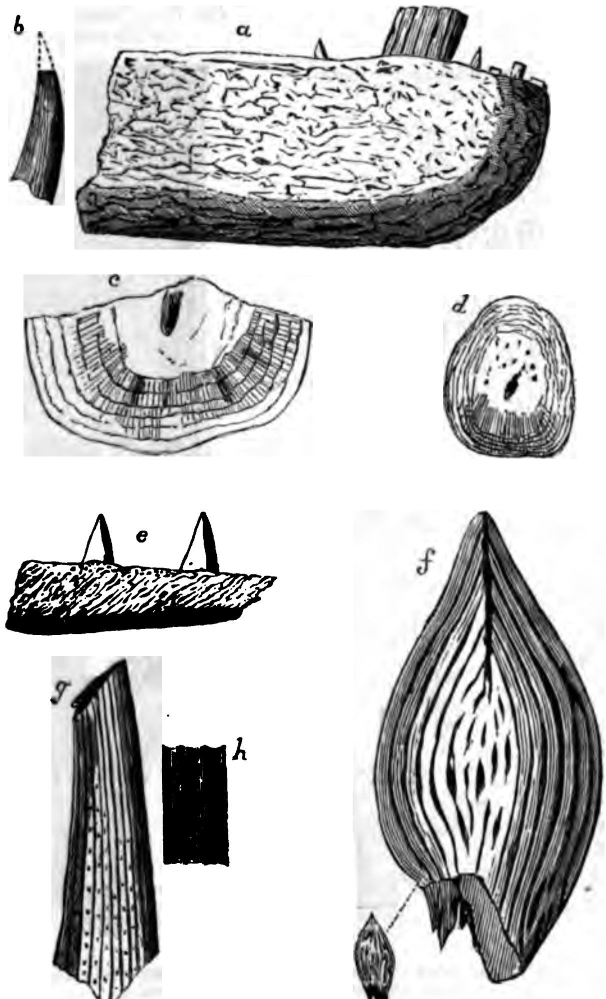


(*a*) Pinnules showing venation. (*b*) Fragment of stipe.
(*c*) Stipe, Pinnules, and remains of fructification.

least pressure, and be tilted in different directions and slipped up or down. The general dip of these beds, however, so far as it can be ascertained by putting together their disjointed portions, appears to be to the north-east or from the older slaty rocks.

The Horton Bluff beds are the geological equivalents of the beds

Fig. 77.—*Placoid and Ganoid Fishes from the Lower Carboniferous.*—Horton Bluff.



(*a, b, c, d*) Portion of Jaw, Tooth, and Scales of *Rhizodus Hardingi*, Dawson—nat. size. The tooth (*b*) is a little too slender.

(*e, f*) Portion of Jaw and Scale of *Acrolepis Hortonensis*, Dawson—the scale magnified.

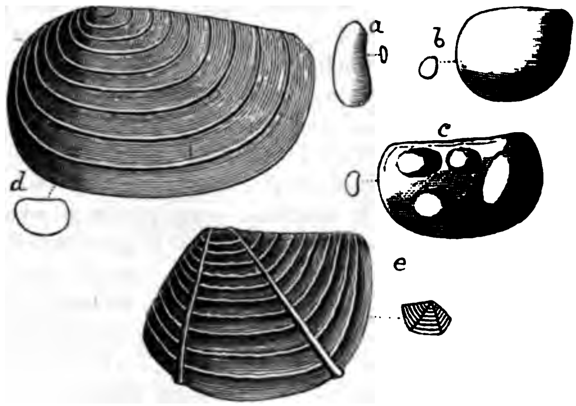
(*g, h*) Spine of *Ctenacanthus* and portion magnified.

previously described as occurring at Hillsborough in New Brunswick; and like them they consist of dark calcareous shales abounding in remains of fish. At Horton, however, the bituminous matter so abundant at Hillsborough, is almost entirely wanting, and the fish-scales and teeth are scattered apart, implying a less amount of vegetable matter and different conditions of deposition. There are also at Horton Bluff numerous bands of coarse limestone, and thick beds of the white granitic sandstone already referred to, as well as gray and red sandstones and marls in the lower part of the section. The most interesting and abundant fossils in this section are the remains of fish, which occur in incalculable numbers; every surface in some of the shales being thickly scattered over with their bright enamelled scales and sharp conical teeth. Some scales are smooth, others finely punctured, others marked with irregular ridges, and others with concentric lines; but all belong to the tribes of ganoids and placoids, which appear to have had exclusive possession of the Carboniferous seas.

I have figured fragments of three of the most common species of the larger fishes whose remains occur at Horton Bluff (Fig. 77). The first is a species of *Rhizodus*, allied to *R. gracilis*, M'Coy, from the Carboniferous shales of Gilmerton, Scotland, but differing from that species in the less curved jaw, not tuberculated, but marked with irregular vermicular lines, and in the thicker, finely striated, less flattened teeth. Scales of this fish much larger than these figured are often seen in the Horton beds. I name it *R. Hardingi*, in honour of the late Dr Harding of Windsor. The jaw and scale represented at *e*, *f*, Fig. 77, belong to a species whose remains are very abundant in the Horton beds, and may be recognised by the pointed and deeply furrowed shining ganoid scales, and the equal and flattened teeth implanted in a dentary bone, whose outer surface is furrowed somewhat like that of the scales. It seems to belong to the genus *Acrolepis*, and I have named it *A. Hortonensis*. The spine of *Ctenacanthus*, figured above, also appears to be new. The same beds contain immense numbers of small scales, probably of *Palæoniscus*. The appearances in these fish-beds, as in the bituminous limestones of the Joggins, indicate the long residence of these animals in the locality, and the gradual accumulation of their harder parts, as successive generations died or were devoured by their larger brethren, and as the waters in which they lived were gradually filled up by the deposition of fine mud. We have also evidence that trees grew on the neighbouring land, for trunks, branches, and leaves of *Lepidodendron* are very abundant, and *Stigmaria* is also found. In one bed, indeed, the trunks of *Lepidodendron* are found rooted in the erect position. They are very numerous but small, the largest being only eleven inches in diameter, and their height is only six

inches. The bed immediately overlying them is filled with prostrate

Fig. 78.—*Entomostraca from the Lower Carboniferous Coal Formation.*—Nat. size and magnified.



(*a*) Cythere. (*b*) Leperditia Okeni. (*c*) Beyrichia. (*d*) Estheria. (*e*) Leaia Leidii.

and flattened branches of trees of the same kind. This is the oldest fossil forest yet known in Nova Scotia, perhaps in the world. Small reptiles tenanted these forests, for Sir W. E. Logan found in 1841 a few footprints of a small creature of this class—the first ever found in rocks of so great age. *Coprolites*, or the fossil excrements of fishes—small bivalve crustaceans—*Leperditia Okeni*, a *Beyrichia*, a *Cythere*, and an *Estheria**—and trails, resembling those made by worms on muddy shores, are also very abundant at Horton Bluff (Fig. 79). There are

Fig. 79.—*Casts in Sandstone of Trails of Worms in Clay.*—Halfway River.

* In the figure (Fig. 78) I have endeavoured to represent these species, and have added the beautiful *Leaia Leidii*, of which I have specimens from rocks of this age at the Strait of Canseau, and which Mr Hartt has found within the limits of the district now under consideration at Parrsboro'. I am indebted to Professor Jones of Sandhurst for the determination of these Entomostracans.

also curious little pairs of oval impressions of the character of those found in the Silurian rocks of Canada and New York, and formerly supposed to be fucoids, to which the name *Rusophycus* was applied. Regarding them, for reasons stated in a paper on the subject published in the Canadian Naturalist, to be burrows of Trilobites or other crustaceans, I have proposed for them the name *Rusichnites*, and have described the present species as *R. carbonarius* (Fig. 80). These and the worm-tracks above mentioned are best seen at Halfway River, between Horton and Windsor. No coal has been found in these rocks.

Fig. 80.—*Rusichnites carbonarius*—Halfway River.

It is evident that in the section above described, we have the occurrence, in the very lowest part of the Carboniferous system, of beds very similar to the Middle Coal formation as it occurs in Cumberland, though sufficiently distinct in their mineral characters and association of fossils to prevent us from confounding the two; an error which has, however, been committed by some of the earlier writers on the geology of the country, and has led to much additional confusion. Beds of similar character and age occur at Halfway River, near Windsor, on the St Croix River, at Upper Rawdon, and at the Gore. In all these localities they skirt the base of the slate hills. On the north shore of Hants, they have been thrown up to the surface by an anticlinal bend of the strata, and are seen at Five Mile River, Noel, Teny Cape, and Walton (Fig. 81). In all these places they appear to underlie the great Lower Carboniferous marine limestones. We have observed a similar fact at Hillsborough, and it also occurs in some parts of the eastern coal districts. We may therefore conclude that in the very dawn of the Carboniferous era, before or coeval with the formation of the great limestone and gypsum beds, conditions somewhat similar to those afterwards so extensively exemplified in the true coal measures prevailed very widely in Nova Scotia. This is not in any way unaccountable, for we have no reason to doubt that marine deposits were forming somewhere when alluvial flats existed at the Joggins, or that there were shores, dry land, swamps, estuaries, and lagoons, contemporary with the seas in which the Hants and Cumberland limestones were formed. At the same time, it is true that in the older Carboniferous period marine deposits were formed in the greatest quantity, while in the later portion of the period there was much more of swamp and estuary deposition.

We may now direct our attention to the strictly marine deposits which rest upon the Horton Bluff beds, and which may be seen along

both sides of the estuary of the Avon, not directly in contact with the shales, etc., which intervene between them and the metamorphic hills, but in such positions as to leave no doubt as to their relative age. One of the best exposures of these rocks in this vicinity is on the right bank of the Avon, immediately above the Windsor bridge, and I shall describe this section in detail, that the reader may at the outset be familiarized with the principal members of that great gypsiferous series which occupies the greater part of the district now under consideration.

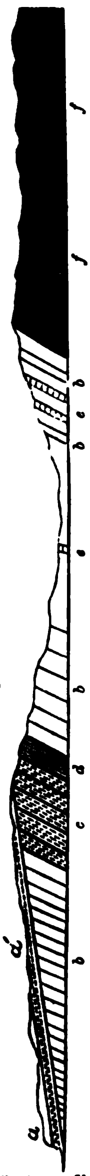


Fig. 81.—*Section at Walton.*

a, a' Triassic Red Sandstone; the lowest bed a hard calcareous conglomerate.
LOWER CARBONIFEROUS.
b Red shale and marl with limestone bands. c Gray and red conglomerate. d Black shales. e Small beds of limestone. f Black shales with calcareous bands.

The first rock seen south of the bridge is a thick bed of red marly sandstone, a soft rock coloured red by peroxide of iron and cemented by carbonate of lime. Below this is a bed of greenish marl, similar to that above in composition, but wanting its colouring matter. Then there is a thick gray limestone, containing enough of fragments of shells to lead us to infer that it may have been made up of such materials, but so decomposed and agglutinated together that it appears now a compact, almost non-fossiliferous, rock. Below this we find again red and greenish marly sandstones. The whole of these beds dip to the north at an angle of 50°. At this point, however, there is a fault, marked by a little gully, cut in consequence of the surface water finding a more ready passage at this place. The next beds seen are again red marls, but dipping to the south at an angle of 55°. On these rests a yellowish limestone, above which are more red and greenish marls.* Next we have another limestone of flaggy or laminated structure, with a number of fossil shells scattered over some of the surfaces, as if they had lived on these surfaces or been scattered over them after death. These shells, like those of the Cumberland Lower Carboniferous limestones, belong to the genera *Productus*, *Spirifer*, and *Terebratula*, all shells of the same family, one of the most singular of the tribes of bivalve shell-fish, and, in so far as we can judge

* According to Mr Hartt, this bed also dips to the N.W., and the break occurs immediately to the south of it.

from the habits of its living representatives, intended to inhabit the depths of ocean. The presence of fossil shells of this tribe is therefore considered by all geologists as conclusive evidence that the deposits in which they occur were formed in the bottom of the open sea. Above this limestone, in the order of succession, we have alternations of marls and limestones, and next a bed of white crystalline gypsum, contrasting strongly in its purity and whiteness with the other beds of more mechanical origin. Here the shore becomes low and no rock is seen, but a little to the eastward we find the great gypsum quarries of Windsor, excavated in the outcrop of a very thick bed, the strike of which would bring it out to the shore just where our section fails, and where the gypsum has been removed partly by the river and partly by the quarrymen who earliest dug this rock for exportation. A little farther to the southward, at the next bluff point, there is a very thick bed of limestone, filled with, or rather made up of, fossil shells of various species and genera, affording a remarkably perfect display of the shelly coverings of the creatures that inhabited the Carboniferous seas.

A descriptive list of the species found here and elsewhere in Nova Scotia, in limestones of this age, will be appended to this chapter, with figures of several of the more characteristic species; and in this place I shall merely mention them generally, and with reference to their living analogues.

At the head of these ancient Molluscs is a *Nautilus*, to a cursory observer not unlike the ordinary Nautili of the Indian Ocean; nor are these ancient Nautili inferior in dimensions to their modern relatives, for at Windsor they may sometimes be seen as much as six inches in diameter. With the Nautilus, we may occasionally find species of *Orthoceras*, a shell of the same family, but straight instead of being whorled. The species usually seen is about one-fourth of an inch in diameter, and four or five inches in length; but I have seen specimens nearly an inch in diameter. The Orthoceras as well as the Nautilus was a chambered or partitioned shell, intended to serve as a float as well as a protection to the animal, which could thus sport on the surface of the sea as well as creep upon its bottom. The inner chambers of these shells are now empty or incrusted with crystals of calc-spar; but the outer chambers are filled with hard limestone, often containing numbers of smaller shells. A species of *Conularia* is also found in this limestone, though less abundant here than in some other places to be hereafter noticed. This shell is believed to have belonged to an animal of the class Pteropoda, which contains little swimming molluscs, furnished with a pair of fins or flappers for

locomotion at the surface of the water. In addition to these shells, we have several species of univalves, resembling the modern Naticas, or whelks and periwinkles, and a number of bivalves belonging to the class *Lamellibranchiata*, and to the genera *Aviculopecten*, *Macroden*, *Cardiomorpha*, etc., all of which may be considered as representatives of the modern bivalve shell-fishes like the Scallops, Mussels, Cockles, etc., though of distinct species.

Other bivalve shells are very numerous, especially a species of *Terebratula*, two of *Spirifer*, an *Athyris*, several species of *Rhynchonella*, and two of *Productus*. These shells belong to a tribe (the *Brachiopoda*) differing in some important particulars from the ordinary bivalve shell-fish, and remarkable as having been very numerous in ancient periods of the earth's history, and comparatively few now. Some of the most abundant species of these genera are figured in subsequent pages. The Terebratula is not unlike some of the modern representatives of the family. The Rhynchonellas are still represented in our modern seas by the Parrot-bill Rhynchonella (*R. psittacea*), now found, though rarely, on the coasts of Nova Scotia. The Productus is remarkable for the great convexity and comparative magnitude of one of its valves, which, as has been conjectured by an eminent zoologist, may have been the lower valve, and have formed a sort of cup containing the animal, and closed by the smaller valve. The *Spirifer* and *Athyris* are distinguished by the presence within the shell of two spiral stony threads, twisted like cork-screws, and connected with the support of the long spiral arms with which all these creatures were provided. These screws are often finely preserved in the Windsor limestone. I may mention here, that in all the Carboniferous limestones of Nova Scotia the shells of this family are usually found with the valves closed and the interior often hollow. This shows that they were not dashed about by violent waves, nor exposed to be filled with fine mud. Yet it does not prove that the death of the animals was sudden, for the hinge of the modern *Rhynchonella* and *Terebratula* is so constructed that it does not gape when dead, like other bivalve shells; but when dead and empty, the hole or notch in the hinge for the peduncle, by which these shells were attached, would admit mud, had this been present, which in many instances seems not to have been the case. The appearances are those which should occur in a bed of shells gradually accumulated in deep and clear water.

Descending a little lower in the animal scale, we have fragments of the stems of Crinoids, which were complicated starfishes, mounted on a stalk. A pretty little branching coral is also very abundant, and with shells, which are entangled in great numbers among its branches,

makes up whole layers of the limestone. There are also sea-mats or *Polyzoa*, of the genus *Fenestella*, some of which spread out into leaves several inches in length.

The only shell in this limestone that appears to be identical with any of the creatures whose remains are entombed in the coal measures of the Joggins is the little *Spirorbis*, which has attached itself to the inside of the outer chamber of some of the larger Nautili, after the death of their owners, and this is evidently a distinct species from the *S. carbonarius*. The reason of the difference in the fossils of these different members of the same geological system is, that one is of marine or deep-sea origin, while the other represents the tenants of the shallow creeks, lagoons, and estuaries of the same period. A similar difference subsists in all modern seas. While, however, distinct species and genera of fossils occur in the littoral and oceanic deposits of the same era, still more decided differences distinguish the formations of one period from those of another; for instance, the Lower Carboniferous limestones from those of the older Devonian and Silurian periods. Hence, if the student once familiarizes himself with the shells of the Windsor limestones, or even with the species represented in the following pages, he has the means of recognising the limestones of the same age in all parts of the country, and of distinguishing them from those of every other formation.

The sandstones and marls of this Windsor section differ little from the similar beds in the coal measures, except that they are less laminated, and less sorted into sand and clay, and contain no vegetable remains—all indications that they were deposited in deep water at a distance from land, and where changes of tides and currents had little influence. The limestone is evidently the result of the growth of shells and corals in the sea-bottom, forming in the course of ages thick and widespread masses, like the coral reefs of the Pacific, with beds of fine calcareous mud and comminuted shells and corals washed from these banks or reefs by the sea. The coral and shell bank itself forms a rich fossiliferous limestone. The material produced around it by the wasting action of the sea becomes a compact earthy limestone, with few fossils, except minute fragments of shells, often only to be detected by the microscope.

The only apparent anomaly in the deposit is the gypsum, which must have been formed by chemical action, or deposited from solution in water. Various explanations may be given of the origin of the veins and masses of gypsum which occur in different geological formations, from the Silurian to the Tertiary, and which, so far as I am aware, are peculiar to the Lower Carboniferous series in no country

except Nova Scotia and Virginia. Different explanations may no doubt apply to different countries and modes of occurrence. For example, in the Upper Silurian of New York, gypsum occurs in such circumstances that it has been supposed to have resulted from the action of local sulphuric acid springs on limestone *in situ* (Dana); while in the case of the gypsum occurring in rocks of similar age in Upper Canada, Dr Hunt supposes that the mineral was deposited from sea-water by its partial evaporation in lagoons, as it is now said to be produced in some of the coral islands of the Pacific,—for instance, Jarvis Island.* Again, there can be no doubt that detached crystals, nodules, veins, and the disseminated gypsum of marls may have been introduced by segregative processes, and by the percolation of gypseous waters. I think it not improbable that there are instances of all or most of these modes in the gypsiferous rocks of Nova Scotia. But for the occurrence of the mineral in so thick and extensive beds, interstratified with marl and limestone, there appears to me to be but one satisfactory theory—that of the conversion of submarine beds of calcareous matter into sulphate of lime, by free sulphuric acid, poured into the sea by springs or streams issuing from volcanic rocks. Modern volcanoes frequently give forth waters containing sulphurous and sulphuric acids. In the volcanic region of Java, for instance, there is a lake of sulphuric acid from which flows a stream in which no animal can live. The water of this stream being probably more dense than sea-water, will naturally flow for some distance along the bottom of the sea, and if it meets with beds of calcareous matter will convert them into gypsum. One of the volcanoes of the Andes gives origin to a similar stream; and the volcanic mountain of Maypo, in the same range, is surrounded by great masses of gypsum, probably produced by the action of sulphurous waters or vapours on the limestone of the region. We know that in the Carboniferous sea of Nova Scotia there were great beds of shells and corals. We also know that the volcanic action which upheaved the metamorphic hills which formed the land of the period, was not quite extinct when these shell-beds were growing. The production of gypsum was a natural consequence of the action of sulphuric acid, evolved from such volcanic regions, on the calcareous beds and reefs. In accordance with this view, the gypsum is found only in association with the marine limestones, though, as might have been anticipated, these last sometimes occur without any gypsum. In all other respects, except this conversion of part of the limestone into gypsum, and some changes probably of similar origin in the

* Hague, quoted by Dana.

associated marls, the Lower Carboniferous series of Nova Scotia and New Brunswick resembles the corresponding formation in Great Britain and the United States, to the fossils of which its shells and corals have also a very marked resemblance, and several of the species are identical.

The rocks we have examined at Windsor may serve as a specimen of those that occupy nearly the whole low country of Hants, the greater part of the Carboniferous area of Colchester, and the long belt extending up the Musquodoboit River. The limestones and gypsums, which form the most important members of the series, appear at a great number of places, and are extensively quarried. The principal localities are the St Croix River, Newport, Kennetcook River, Walton, Noel, White's or Big Plaster Rock, and other places on the Shubenacadie, Brookfield, Onslow, Stewiacke, and Upper and Middle Musquodoboit. One of the finest natural exposures of gypsum in the province is on the St Croix River, a few miles from Windsor. Here the gypsum forms a long range of cliffs of snowy whiteness. This cliff consists principally of the variety of gypsum named "hard plaster," or "sharkstone," by the quarrymen; the latter name referring to the rough shagreen-like texture of its weathered surfaces. It is *Anhydrite*, or gypsum destitute of the combined water which gives to the ordinary variety its softness and its usefulness as a material for modelling and plastering. Anhydrite occurs in connexion with most of the beds of gypsum, generally forming separate beds, but sometimes mixed in large masses or nodules, or minute transparent crystals, with the common plaster. It is not at present applied to any useful purpose, being too hard to be profitably ground for agricultural uses. It may, however, be used as a substitute for marble, for the internal decoration of buildings, and some of the varieties in the cliffs of the St Croix are well adapted to this use, and could be procured in any quantity.

Having thus described the Lower Carboniferous rocks as they occur at Horton and Windsor, I shall now attempt to give a general view of their arrangement in the area now under consideration, as well as their relations to certain limited tracts of coal measures which rest upon them, especially in the northern part of the district. To effect this, I shall take advantage of the sections afforded by the Folly and De Bert Rivers, and the Shubenacadie; and shall describe these as they would appear to an observer descending the southern slope of the Cobequids, following the course of the Folly River, crossing Cobequid Bay, and ascending the Shubenacadie to the Grand Lake.

On the Folly River, about eight miles from its mouth, we leave

the ancient metamorphic slates of the hills, and enter the Carboniferous system, which we find resting on the edges of the slates, and dipping to the south. The first rock seen is conglomerate, in enormously thick beds, and made up of fragments of all the rocks of the hills. Passing this ancient beach of the old Carboniferous sea, we find, without the intervention of any marine limestones, coal measure rocks, consisting of gray sandstones and dark shales, with a few thin seams of coal, and abundance of leaves of *Cordaites*, and a few *Calamites* and *Stigmaria*. Succeeding these beds is a great thickness of red and gray sandstones and shale, with a general dip to the southward, though broken by so many faults that it is not easy to form an estimate of their aggregate vertical thickness. Finally, we observe, as we descend the river, these same sandstones and shales dipping at high angles to the northward. They are then overlaid by the new red sandstones, and we see no more of the Carboniferous rocks till we approach the mouth of the Folly and De Bert, where we find the Lower Carboniferous limestone, gypsum, and conglomerate, mentioned in our description of the New Red, and dipping to the north-east. The fossils of this limestone are the same species found at Windsor and elsewhere in beds of the same age. We have here a broken and disturbed coal measure trough, constructed in the same manner with that of Cumberland, but on a much smaller scale, and probably including only the lower members of the Coal formation. The absence of the Lower Carboniferous limestone near the hills corresponds with what we observed in Cumberland, and is accounted for by the circumstance that the Cobequids formed the shore of this ancient sea, while the limestones could be formed only in deep water at some distance from the turbid surf and the pebbly beach—an arrangement corresponding exactly with what is observed in the modern coral-reefs of the Pacific.

We can trace the Coal measure band, of which the Folly River gives us a cross section, all the way from Advocate Harbour, near Cape Chiegnecto, to the upper part of the Salmon River, where it adjoins the Carboniferous district of Pictou. It is everywhere much broken and disturbed; and though it widens considerably toward its eastern extremity, it nowhere attains a great development, either in horizontal extent, or in the magnitude of its coal-seams. From Advocate Harbour to Partridge Island this belt consists principally of greatly contorted and somewhat altered shales and sandstones, containing a few fossil plants, some scales of fishes, and in places abundance of shells of *Naiadites*. In a bed near Partridge Island, Dr Harding of Windsor found, several years since, a fine series of

footprints, probably of a small reptilian animal. More recently other footprints, of larger size, and referable to the genus *Sauropus*, were found in these beds by J. M. Jones, Esq., F.L.S., of Halifax. These indications of vertebrates of the land will be noticed in a subsequent chapter. Eastward of Partridge Island, in Clarke's Head, we find the Lower Carboniferous limestones somewhat altered, with beds of common gypsum, and a beautiful purple variety of anhydrite. At Moose River and Harrington River, the black shales and gray sandstones again appear. In Economy, we have these and the Lower Carboniferous limestone with its characteristic fossils, and on the banks of the Portapique and Great Village Rivers, the whole series is well exposed, with appearances similar to those observed in the Folly. Eastward of the latter river, the Coal formation band widens rapidly. On the Chiganois and North Rivers, it contains bituminous limestones, with *Cyprids* and fish-scales; thick beds of shale, with clay-ironstone; several small coals, the largest, I believe, about eighteen inches in thickness; and in the beds associated with these coals are fossil plants of several of the species described in connexion with the Joggins section. On the North River also we find the lower limestone underlying the Coal measures at the base of the mountains, and re-appearing, in greatly increased thickness and associated with beds of gypsum, on the south side of the trough. Still farther eastward, on the Salmon River, there is a bed of good coal nearly two feet in thickness, and associated with shales, containing fine specimens of *Ulodendron*, *Ferns*, and other Coal formation fossils.

Applying to this narrow Coal formation trough the information we have obtained from the Joggins section, we may conclude that along the base of the Cobequid Mountains, on their southern side, a band of swamps and shallow and land-locked waters existed contemporaneously with the wider tract of the same description on the northern side of the mountains; and it is quite possible that the northern edge of the Lower Carboniferous limestones may have formed a barrier-reef, separating this narrow littoral band from the more open sea without. In its present condition, this Coal formation belt of the south side of the Cobequids presents many difficulties to the geologist. The various movements which have taken place along the south side of the mountains, and which have probably continued up to the close of the New Red period, have shattered these rocks in lines parallel to and at right angles with the hills, and have also bent and contorted them in a remarkable manner. In this respect, the Carboniferous rocks on the Cumberland side of the hills differ very much from those of the Colchester side; the former being very little disturbed in comparison.

Crossing Cobequid Bay from the mouth of the Folly to that of the Shubenacadie, we find the first rock that appears at the mouth of the latter to be a black laminated crystalline limestone without fossils, and supporting a great thickness of marls and gypsum similar to those of Windsor. I spent several days in exploring this section in 1842, in company with Sir Charles Lyell, and the late Mr George Duncan of Truro. The limestone and marls resting on it dip to the south-west. It thus appears that the Lower Carboniferous beds on the opposite sides of the bay dip inland, so that the bay forms, in so far as these rocks are concerned, an *anticlinal valley*—a somewhat rare occurrence in this region, where the beds of sedimentary rocks usually dip away from hills rather than from depressions. The rocks in the banks of the Shubenacadie are, however, much broken by faults, though the general dip in the lower part of the river appears to be to the southward. The rocks succeeding the "Black Rock" limestone, for about three miles up the estuary of the Shubenacadie, consist principally of soft marly sandstones filled with veins of reddish fibrous gypsum, which run in every direction, and form a network so complicated that it is difficult to understand how the rocks could have been supported in such a manner as to leave open the fissures which the gypsum fills. It is possible, however, that these cracks were not all open at once, but were produced by different movements to which the mass has been subjected; and there is another way of accounting for this appearance, to be stated shortly. There are also a few wide veins filled with the peroxide of iron and sulphate of barytes. The former is in part in the red ochrey state, and in part in the state of red and brown hematite, often in beautiful coralloidal forms with an internal fibrous structure. The barytes is in small tabular crystals. These veins also contain oxide of manganese and calc-spar. Their contents were probably introduced by water, rising from rocks beneath which afforded these materials.*

The reader will observe that the veins of gypsum contained in these rocks are very distinct from the large beds of the same mineral. The latter were formed as horizontal layers at the same time with the containing beds. The former have filled up cracks opened after the beds were consolidated. The fibrous texture, which the gypsum veins nearly always display, arises from the circumstance that little slender prisms of the mineral have sprouted forth from the sides of the fissures until they filled them. Hence they always stand at right angles to the sides of the vein. Similar appearances are observed in the greater

* For the manner in which these minerals may have been formed, see descriptions of mineral veins at Five Islands and Acadia Mine.

number of minerals lining or filling veins or fissures. I am inclined to believe, however, that the fibrous gypsum in the gypseous marls has been produced in a different manner from the "combs" of quartz and other minerals found in the fissures of slate, trap, etc. The gypsum veins show no signs of having met in the middle, though, they often appear to have been added to at each side; and we may infer that the prisms of gypsum grew by additions to each end, furnished by water permeating the rock, and *pressed the sides of the fissure apart* as they grew in length. Veins of fibrous ice are formed in this way in banks of clay, exerting an enormous expansive force, sufficient to break down the strongest retaining walls; and when circumstances are favourable, these clusters of icy prisms may be seen to raise objects lying on the surface of water-soaked clays to the height of several inches. Wherever segregation and crystallization are going on in the fissures of rocks, similar effects may be produced; and it is quite possible that they play an important part in geological dynamics. It is at least not unlikely that some of the remarkable contortions and dislocations observed in the gypsiferous rocks of Nova Scotia may have been produced in this way.

These marly rocks contain a bed of anhydrite and common gypsum, in addition to the gypsum veins above mentioned.

Proceeding to the southward, along the eastern bank of the river, we reach a high cliff of brownish-red and gray sandstones, dipping S. 30° W., and containing a few fossil plants. These beds probably overlie those previously noticed, and much resemble the sandstones that in the Joggins section intervene between the lower limestones and the Coal measures. To the southward of this cliff, which is called the Eagle's Nest, the shore for some distance shows no section. On the west side, however, where the rocks corresponding to the Eagle's Nest form a high cliff, they are separated by a fault from an immense mass of gypsum named White's or the Big Plaster Rock, and one of the principal localities of the extensive gypsum trade of this river. The Big Rock at one time presented to the river a snowy front of gypsum, nearly 100 feet in height; but it has been greatly reduced by the operations of the quarrymen, who bring down enormous quantities by blasting. It is a massive bed, arranged in thick layers, and the whole bent into an arched or almost cylindrical form. In its lower part there is much anhydrite, and also dark laminated limestone, having on its surfaces of deposition immense numbers of flattened shells of *Conularia*. A compact limestone, containing *Terebratulæ*, also appears near the bottom of the mass. Faults, denudation, and disturbance render it quite impossible to discover in the river section

the relations of this mass of gypsum to the neighbouring beds. Its nearest neighbour to the south is a series of dark shales and gray sandstones, with a few fossil plants of Coal formation genera. These beds are very much contorted, but have a prevalent dip to the south. I have no doubt that they are equivalents of the Horton Lower Carboniferous shales. A sheet of paper could hardly have been crumpled into more fantastic curves than these beds, no doubt once flat and horizontal. This is an effect of lateral pressure acting upon them while in a soft state, and it testifies to the enormous forces of this description which have been applied before these beds attained their present hard and brittle condition. These beds appear on both sides of the Five Mile River, a stream running into the Shubenacadie at right angles, and they extend along the course of this stream and that of the Kennetcook, which is continuous with it, though flowing in the opposite direction, far into the interior of Hants. On the Kennetcook, they contain a small seam of coal, and have more the aspect of true Coal measures than any other beds I have seen in this county. But from recent observations made by Professor How of Windsor, I am inclined to believe that all these beds are Lower Carboniferous.

Hitherto we have found few fossils in this section; but at the next point above the contorted Coal measures of Five Mile River, we have a grand example of a fossiliferous limestone, forming the cliff named Anthony's Nose. This limestone, which is a mass of corals and shells similar to those noticed at Windsor, is about 40 feet thick, and stands quite on edge, projecting like a huge wall into the river. Soft marls rest against each side and include a bed of gypsum, and, at a little distance, a thick bed of this mineral appears with an arched stratification. On the opposite side of the river there are other limestones and gypsums, also very much disturbed; and, immediately adjoining them on the south, there is a cliff of reddish sandstone, like that of Eagle's Nest, and nearly in a horizontal position.

Beyond this place, the river section is not continuous, but gypsum and limestone, full of marine shells, appear in several places, and the marls and red sandstones occasionally peep forth from beneath thick beds of boulder-clay. Finally, at Gay's River, Key's on the Shubenacadie, the lower end of Grand Lake, and Nine Mile River, the gypsum and limestone are seen almost in contact with the ancient metamorphic slate and quartzite which bound this Carboniferous district on the south.

At one of these places, Key's, on the old Halifax road, one of the beds of gypsum contains white and bleached-looking quartzose pebbles and sand. In this case, it is probable that the acid which produced

the gypsum acted on a mass of calcareous matter, mixed with sand and gravel, which became entangled in the gypseous mass produced. Such instances of the enclosure of foreign bodies in gypsum are rare. I have, however, seen layers of sand and earthy matter, and fragments of limestone, and in a few instances vegetable remains have appeared in the earthy layers. Some beds of gypsum are also blackened by bituminous matter, derived no doubt from animal or vegetable substances.

Over nearly all the beds of gypsum in this region, the whole surface is riddled by funnel-shaped cavities, named "plaster-pits," by the aid of which the gypsum may be traced in localities where it does not itself reach the surface. These pits are well exposed in the face of the "Big Rock" formerly described. They are produced by the solvent action of the surface water penetrating through the fissures of the gypsum, in a manner which we shall have better opportunities of studying when we arrive at the gypsiferous districts of Cape Breton.

The section formed by the long narrow tideway of the Shubenacadie, and continued less perfectly along its fresh-water portion, enables us to form an idea of the structure of the southern part of the Hants and Colchester area, across its whole breadth. It is evident that the regular succession of the beds has been much disturbed by faults or fractures, most of which have a direction approaching to east and west. They have shifted the masses of beds, so that we cannot now, without extensive investigations of all the minor sections afforded by tributary streams, put them together into a continuous series. The following is the nearest approximation to such a restoration of the original arrangement that I can offer:—*1st*, From the mouth of the Shubenacadie westward to Walton and Cheverie, the shales which lie at the base of the Carboniferous system appear in several places, and immediately resting on them are red sandstones and marls, with limestone and gypsum; and the lowest bed of limestone is a laminated dark-coloured crystalline bed without fossils. *2dly*, The red sandstones and marls with gypsum and limestone, form a wide band extending through Hants to the Avon estuary, south of these lowest members of the series; and in places there appear, in and over these beds, gray and brown sandstones with fossil plants. *3dly*, Along the course of Five Mile and Kennetcook Rivers, extend rocks having the aspect of the Lower Coal formation, which appear to be thrown up along an anticlinal line. *4thly*, Immediately to the south of these, we again find the red marls, gypsum, and limestone, forming a second broad belt, extending from Rose's Point and Admiral's Rock, on the Shubenacadie, through Newport to Windsor. This is the re-appearence of the same part of

the formation seen below White's Plaster Rock, and it is worthy of note, that it is here much more fossiliferous than in the lower part of the river. *Lastly*, From the point of the Gore Mountain, along the base of the Douglas and Rawdon Hills, we can trace the Lower Carboniferous shales all the way to Horton. That trough-shaped arrangement, so characteristic of the Carboniferous rocks in this part of Nova Scotia, can therefore be traced even in the fractured section of the Shubenacadie.

Eastward of the Shubenacadie, the Carboniferous district splits into three branches, entering between the hilly ridges of the metamorphic country to the eastward. The most northern of these passes along the valley of the Salmon River, and is connected with the Pictou district. The second passes up the valley of the Stewiacke River. The third forms a narrow band extending from the Grand Lake nearly to the sources of the Musquodoboit River. In the northern branch, both the Lower Carboniferous and Coal formation series appear, as we have already noticed; but in the two others the Lower Carboniferous rocks prevail almost or altogether to the exclusion of the Coal formation. In one place only on the Lower Stewiacke, do rocks having the aspect of Coal measures appear. In the Stewiacke branch, which, in the period in question, must have been a sheltered bay or channel, the corals and shells of the limestones attain a magnitude and perfection not, so far as I know, equalled in any other part of the province. Gypsum also abounds in this branch, and in one place there is a large deposit of sulphate of barytes. In the southern or Musquodoboit branch there is much gypsum and also limestone; but the latter does not appear to be rich in fossils. I have found in it only a few fragments of Crinoids.

As the district just described presents the most important development in the province of the Lower Carboniferous series, I have employed it to introduce the reader to that part of this great system of rocks, just as the Cumberland district served a similar purpose in relation to the Coal measures; and I may now conclude by a review of the condition of Southern Hants and Colchester at the time when the marine limestones and gypsums were produced. At this period, then, all the space between the Cobequids and the Rawdon Hills was an open arm of the sea, communicating with the ocean both on the east and west. Along the margin of this sea there were in some places stony beaches, in others low alluvial flats covered with the vegetation characteristic of the Carboniferous period. In other places there were creeks and lagoons swarming with fish. In the bottom, at a moderate distance from the shore, began wide banks of shells and

corals, and in the central or deeper parts of the area there were beds of calcareous mud with comparatively few of these living creatures. In the hills around, volcanoes of far greater antiquity than those whose products we considered in a former chapter, were altering and calcining the slaty and quartzose rocks; and from their sides every land-flood poured down streams of red sand and mud, while in many places rills and springs, strongly impregnated with sulphuric acid, were flowing or rising, and, entering the sea, decomposed vast quantities of the carbonate of lime accumulated by shells and corals, and converted it into snowy gypsum. Of the creatures that may have crept or walked on the land, we know nothing except the hint afforded by the few footprints found by Logan and Harding in the shales of Horton and Parrsboro', and which testify that reptilian life in some of its lower forms had already begun to exist. The sea had already attained almost its maximum of productiveness in fishes and creeping things, but we have no reason to believe that the land had yet received from its Creator any of those higher creatures which were destined to be introduced in a subsequent "creative day."

Useful Minerals of the Hants and Colchester District.

Gypsum is at present the principal product of this district. It is largely quarried at Windsor, Newport, Walton, Shubenacadie, and a number of other places; and, in 1861, 124,241 tons* were quarried, amounting to the value of over $83,000 at the ports of shipment. The greater part of this large annual produce of gypsum is exported to the United States for agricultural purposes. The quantity of gypsum in this district is enormous, and probably cannot be exhausted by any demand ever likely to occur. It is now quarried only in the places most accessible to shipping, and its small value per ton indicates the facility with which it can be obtained, in a country in which the price of labour is by no means low.

Limestone is also extremely abundant in this district, and might be quarried and exported as readily as the gypsum. Limestone being abundant in New Brunswick and in the United States, is not, however, in demand for exportation, and the wants of the country are at present small; especially in a district in which the land is in most places well supplied with calcareous matter. It may be anticipated, however, that a demand will arise for lime to supply the wants of the shore-districts, which are almost entirely destitute of this mineral.

Iron Ore occurs in veins traversing the Lower Carboniferous lime-

* 118,215 in Hants and 6026 in Colchester.

stones and sandstones near the mouth of the Shubenacadie and in Brookfield. The ores are red ochre, red hematite, and brown hematite, associated with sulphate of barytes and calcareous spar. One of the veins of the east side of the Shubenacadie, near its mouth, is of considerable magnitude, and it is probable that such veins, more or less valuable, will be found in the country between this place and Brookfield, where, however, the quantity of iron seems much greater than on the Shubenacadie.

At Brookfield, about 2½ miles east of the Brookfield station on the railway between Halifax and Truro, a deposit of fibrous brown limonite has been discovered, and has been examined by Mr Barnes of Halifax and Professor How of Windsor, to whose reports I am indebted for the following information:—The ore occurs in large boulders, scattered over a surface of 50 acres, and some of them containing three to four tons of ore. They are apparently nearly *in situ*, as veins of the same mineral are found in the locality, enclosed in a brownish ferruginous quartz rock or hardened sandstone, of a character frequently seen in this part of Colchester, and which is either of Devonian or Lower Carboniferous age—probably the former. The ore occurs at or near the junction of these rocks with ordinary Lower Carboniferous shales and limestones, which would seem to be unconformable to them. Sulphate of barytes, of excellent quality, is found in the latter rocks at no great distance, associated with iron ore, and probably under the same conditions in which these minerals occur near the mouth of the Shubenacadie.

The ore of Brookfield is of excellent quality, and should the quantity prove considerable when the mine is opened in the solid rock, its vicinity to the railway will render it a very valuable property. The masses on the surface have no doubt been left by the denudation or washing away of the containing rock, and would seem to indicate an important deposit; but veins and masses of this kind are often very irregular and uncertain, so that, to determine the real value of the deposit, better openings than those which now exist would be required.

Ores of Manganese.—These are found at several places in this district, in veins or disseminated in nodules in the Lower Carboniferous limestones. The most important localities at present are Teny Cape in Hants, and Onslow Mountain in Colchester. From the former place about 1000 tons, worth £8 to £9 per ton, are stated by Professor How to have been extracted up to this time. The following account of the Teny Cape locality is taken from a paper by Professor How in the Philosophical Journal for March 1866:—

"*Pyrolusite.*—This species is found at numerous localities in different parts of the province, and is now being mined in considerable quantity at one of them, viz., at Teny Cape in Hants Co., about five miles from Walton, where about a thousand tons have been got out within the last two years, the bulk of which has been readily sold in England. It occurs here in the form of nodules of irregular, generally rather flattened shape, of all sizes, from that of a bean up to that of a man's head, or even twice as large, and weighing proportionately up to about twenty-five pounds. These masses lie loose in a bed of 'soil' about a foot thick and a foot below the surface: they consist of pyrolusite and psilomelane. Some feet below this bed, in a gray and brick-coloured limestone containing magnesia, the ore is found, in very thin deposits, which, from the easily separable nature of the rock, can be laid bare in sheets, and also in 'pockets' or interrupted chains of deposits of very variable dimensions, sometimes but a few inches in depth, and thickening out to several feet. I have seen one egg-shaped mass exposed *in situ* estimated to be of three tons weight. One of these 'pockets,' running east and west at a depth of 15 feet from the surface, was about 72 feet in length, varied in thickness from 6 inches to 14 feet, and was practically exhausted on the removal of about 130 tons of ore. A second runs parallel with this, at a depth of 30 feet from the surface, and has been found to extend at least 105 feet: it had yielded up to August last about 300 tons of ore; and a large quantity remained. Below this, again, at a depth of 50 feet from the surface, other deposits have been met with, the form and dimensions of which have not, so far as I know, been fully made out, but which have afforded many tons of good ore. The whole thickness of the limestone holding manganese is estimated at about 300 feet.

"The minerals associated with pyrolusite at Teny Cape are iron ore (brown hematite, I believe), barytes, and calcite. The first of these is occasionally found at the line of junction of the ore and rock, which, as before mentioned, is sometimes red. The barytes is of pure white colour, is often disseminated in varying quantity through the pyrolusite, and is probably constantly present in all but the pure crystals of the species. The calcite is also occasionally imbedded, in transparent crystals, but more often exists as an incrustation; it sometimes forms specimens of great beauty, when it lies in opaque snow-white mammillary masses of finely crystalline structure, or in piles of nail-head crystals, half an inch or an inch across, of gray or snow-white colour, on black lustrous masses of well crystallized pyrolusite.

"The pyrolusite found at Walton is sometimes attached to brown hematite in a reddish limestone resembling that at Teny Cape.

"The forms of the mineral are various. It is generally highly crystalline. The masses at Teny Cape are sometimes of a gray black, and consist of closely packed fine long fibres, sometimes are made up of bunches of stellated short crystals, and often of distinct and lustrous jet-black crystals with perfect terminations: all these varieties yield readily to the knife. The Pictou ore (found at a distance of about seventy miles) is coarsely fibrous. The greater part of that from Walton is in soft, black, lustrous, short crystals; one specimen, however, has been met with almost crypto-crystalline in structure and of bluish-gray colour, closely resembling the ore from Saxony. A very similar specimen from Amherst, Cumberland Co., forty miles from Walton, gave on analysis in the air-dry state,—

Water	0·61
Binoxide of manganese . .	97·04
Gangue and loss . . .	2·35
	100·00

The insoluble matter (gangue) was brownish white, and most probably consisted of barytes.

"I have no doubt that specimens of the greatest possible purity could be selected at Teny Cape. I have examined a good many samples of dressed ores, and have commonly found from 80 to 93 per cent. binoxide; a specimen obtained at a depth of 50 feet from the surface, taken as a sample of dressed ore, and weighing about a quarter of a pound, gave me in the air-dry state, in summer, 93·83 per cent. binoxide of manganese, with barytes and a mere trace of iron. It is a very valuable property of this ore, as regards its use by glass-makers, that, when cleaned, it contains remarkably little iron. The first shipment sent to England, consisting of about seven tons and a half, gave, on analysis in Liverpool, 91·5 per cent. binoxide, and less than a half per cent. of iron.

"South of Teny Cape, at a distance of some ten miles, large nodules of manganese ore are found resembling in appearance those described as occurring in the 'soil' at the former place. One of these weighed 180 pounds; a fragment from another, weighing thirty-five pounds, was examined by Mr H. Poole, a pupil of mine. The mass was black, of unequal hardness, portions scratching apatite, and therefore about 5·5, while the rest yielded easily to the knife. The powder of the harder parts was nearly as black as that of the softer. The water of composition was found by weighing in chloride of calcium; the binoxide of manganese by oxalic acid; the results were these:—

Hygrometric water	1·660
Water of composition	3·630
Peroxide of iron	·603
Soluble baryta	·724
Insoluble (barytes?)	1·728
Binoxide of manganese	84·620
	92·965

which show that the mass consisted chiefly of pyrolusite. That the associated mineral was psilomelane follows from its appearance and hardness, the colour of its powder, and the amount of water contained, which is too little for manganite, and too much for any of the other manganese minerals."

"It is an interesting fact that silver, to the amount of five ounces to the ton of ore, has been found in a specimen from Teny Cape, on assay by J. Taylor and Co., in London."

The deposit of manganese ore on the property of the "Onslow East Mountain Manganese and Lime Company" occurs under similar geological conditions with that of Teny Cape, and has been very favourably reported on, both as to the quantity and quality of the mineral, by Mr Barnes, Professor How, and Dr Honeyman.

Galena, or sulphuret of lead, is found in disseminated crystals and small veins in limestone at Gay's River and some other places. Some specimens which I have examined contain a considerable proportion of silver; and one bed of limestone at Gay's River, pointed out to me many years ago by the late Mr G. Duncan, has so much disseminated galena that favourable opinions have been expressed as to its economic value; but I am not aware that it has yet been worked. The occurrence of valuable ores of lead in the Lower Carboniferous limestones in England and other countries gives some reason to hope that more important indications of this metal may yet be discovered. *Sandstone* suitable for building purposes occurs at Horton, Halfway River, Windsor, the Shubenacadie, and probably many other places; but not in such quantity nor of such excellent quality as in the Coal formation of Cumberland and Pictou. For this reason it may not, for some time at least, be worthy of attention as an article of export, but it can be abundantly obtained for domestic use.

Clays suitable for bricks and common pottery can also be procured in large quantity on the Shubenacadie. Yet in the last census Hants made no return of bricks, while the quantity made in Colchester was stated at 420,000.

Coal in small seams occurs at Salmon River, North River, Chiganois

River, De Bert River, Folly River, and Great Village River, in the Coal measure belt extending along the south base of the Cobequids, and these small seams appear at intervals as far west as Cape Chiegnecto. I have seen the outcrops of these coals in several places, and according to my own observations and the best information I can obtain from others, none of them exceed eighteen inches of clean coal. Better seams may possibly be found, but the measures are exposed by so many river sections that it seems unlikely that they should have so long escaped observation. Indications of coal have also been observed in the Coal measure band extending from Lower Stewiacke toward and along the Kennetcook River. These measures are not well exposed, and I believe that nothing definite is known as to their real value. The occurrence of coal in this central district would, however, be of so great importance to the province, and to the success of its main line of railway, that the subject well merits a thorough investigation.

Sulphate of Barytes, which is manufactured into a pigment employed as a substitute for or adulteration of white lead, has been quarried on the banks of the Stewiacke. The deposit, which at first appeared to be large, is stated to be now exhausted, at least in so far as it can be reached by the ordinary operations of the quarryman. As already stated, this mineral is said to occur in connexion with the iron deposits of Brookfield.

Brine Springs issue from the Lower Carboniferous rocks in several parts of Nova Scotia. In the district now under consideration they are found at Walton in Hants county. A specimen analyzed by Professor How gave, in the imperial gallon of water,—

Chloride of sodium, or common salt .	787·11	grains.
Sulphate of lime	161·16	„
Carbonate of lime	14·73	„
Chloride of magnesium	4·48	„
Carbonate of magnesia, carbonate of iron, and phosphoric acid	traces.	
	967·48	

The large quantity of sulphate of lime contained in this brine is, without doubt, connected with the abundance of gypsum in the Lower Carboniferous series, and points to the association of gypsum and common salt, probably in the gypseous marls. Professor How expresses a favourable opinion of this and other saline springs in Nova Scotia as profitable sources of common salt.

Gold.—A deposit of this metal, perhaps of even more interest in a geological point of view than practically, though apparently of some value in this last respect, occurs in the Lower Carboniferous conglomerate at Corbitt's Mills, four miles north of Gay's River in Colchester county. It was described in the Canadian Naturalist for 1864 by Mr C. F. Hartt, and Dr Honeyman has favoured me with manuscript notes of a visit to the place in 1866. From these sources I extract the following information:—The locality is at the junction of the Lower Carboniferous conglomerate with the slate and quartzite, forming the extremity of the ridge separating the valleys of the Stewiacke and Musquodoboit Rivers. The slates belong to the Silurian gold-bearing formation, and contain small but rich auriferous quartz veins. The conglomerate is formed of the debris of these older rocks, and gold occurs in it exactly as in modern auriferous gravels, being found in the lower part of the conglomerate, and also in the hollows and crevices of the underlying slate. The fact is interesting, as showing that the gold veins existed in their present state at the beginning of the Carboniferous period, and that the causes which produce the more modern gold alluvia were then in operation. By a later repetition of this process, the drift or boulder clay which overlies the conglomerate is at this place also slightly auriferous. In the Report of the Commissioners of Mines for 1866, it is stated that the high prices charged for land at this place had interfered with the operations of those desirous of opening the deposits; but that a crushing-mill had been erected, and that mining operations on such a scale as would prove the value of the deposit would soon be undertaken. Should they prove successful, they will present a curious and perhaps unique instance of mining for gold in rocks of the Carboniferous system, and will stimulate inquiry as to the possible productiveness of the Lower Carboniferous beds in other places where they come into contact with the older auriferous slates, as is the case in many places in the valleys of the Stewiacke, Musquodoboit, and St Mary's Rivers, as well as in the eastern part of Hants.

CHAPTER XVI.

THE CARBONIFEROUS PERIOD—*Continued.*

THE MARINE FOSSILS OF THE CARBONIFEROUS LIMESTONES.

THE short list of those published in the first edition of "Acadian Geology" was derived principally from that given by Sir C. Lyell in his "Travels in North America," on the authority of M. De Verneuil, who examined the collections made by Sir Charles. This list was, however, necessarily very imperfect; and since it was prepared, a large amount of additional material has accumulated, and some important investigations have been made. In 1862, being aware that Mr T. Davidson was engaged in the examination of British Carboniferous Brachiopods for the Palæontographical Society, I sent to that eminent palæontologist, the best living authority on Brachiopods, a collection of these shells, representing all the species known to me, and he very kindly undertook their examination along with those in Sir C. Lyell's collection. The results were given to the world in an able memoir in the Proceedings of the Geological Society of London for 1863. This was an important step in advance; but the other fossils, not Brachiopods, still remained untouched. In the meantime, Professor How of Windsor, and his pupil, H. Poole, Esq., jun., had made some interesting discoveries at Windsor and Kennetcook, and a new Trilobite from the latter place, sent to me by the former gentleman, was described by Mr Billings in the Canadian Naturalist, under the name *Phillipsia Howi.* About the same time, Mr C. F. Hartt undertook the work of collecting carefully and systematically at Windsor and Stewiacke; and not only found several new species, but developed characteristic differences in the fossils of the successive limestones of the Windsor section. Mr Hartt proposed to prepare for publication the results of these researches, and has written a paper on the subject for the Canadian Naturalist; but a voyage to Brazil and subsequent engagements have prevented him from completing the task of describing and fully cataloguing the species. In these circumstances, I have been obliged to prepare such a list as was possible under the circumstances. It is much in advance of that previously given, and will, I trust, aid materially in subsequent

investigations; but it is still incomplete, and will no doubt be much modified by future investigations. In preparing it, I have been much aided by the notes and collections of Mr Hartt, by specimens furnished by Professor How and Mr Poole, and by the extensive palæontological knowledge of Mr Billings. I shall copy Mr Davidson's descriptions of the Brachiopoda, and shall give as many figures as possible, to aid students and collectors, and to facilitate comparisons with the fossils of other countries.

Before proceeding to give the list of these fossils, there are two important geological questions in relation to them which must engage our attention. The first is the possibility of dividing the marine limestones of the Carboniferous period into different stages or sub-formations. The second is the precise geological and geographical relations of the fauna.

With regard to the first of these points, I have myself indicated the possible division of the Lower Carboniferous limestones into an upper and lower series, and also the fact of some of the species extending their range to the Upper Coal formation. But Mr Hartt has gone into the subject much more minutely, and I shall give, in the first place, a summary of his results, in connexion with my own.

In the section at Windsor above referred to, several limestones appear; but owing to faults and bends of the beds, their precise relations to each other are not very evident; still an approximation to these can be obtained; and I believe that the order given below will be found in the main to be an ascending one—each limestone being separated from those next it by a considerable thickness of sandstone, marl, or gypsum.

(*a.*) Limestone of Avon Bridge (Avon Limestone, Hartt)—*Spirifer Limestone.* A thick band of compact, laminated, oolitic, and brecciated limestone, not highly fossiliferous, but containing *Productus cora* (var. *Nova Scoticus*, Hartt)—*Spirifer glaber*, *S. octoplicatus*(?), *Rhynchonella Ida*, *Phillipsia* and *Bakevellia*, and an Arca-like shell which I have not seen elsewhere (*A. punctifer*). This is a very thick and important series of beds, and appears to correspond with the lowest Carboniferous limestone as seen in other localities.

(*b.*) Limestone, laminated, oolitic, compact, and concretionary—*Crinoidal Limestone.* Abounds in fragments of crinoids, minute shells of a *Dentalina*, *Serpulites*, and small Gasteropods, especially species of *Pleurotomaria*. *Bakevellia antiqua* also abounds in it, and it is a remarkable repository of minute shells, many of which are yet undescribed. A limestone similar to this exists apparently in a similar position on the Shubenacadie River.

(*c.*) Gray or bluish earthy limestone, laminated and concretionary (Kennetcook Limestone, Hartt)—*Zaphrentis Limestone.* Contains *Phillipsia Howi*, *Zaphrentis Minas*, *Cyathophyllum Steviacum*, *Spirifer striata*, *Athyris subtilita* (?), *Productus semireticulatus*, *Strophomena analoga*, *Edmondia Hartti*, *Cypricardia insecta*, *Orthoceras laterale*, *Stenopora*, and *Fenestella.* This limestone has been recognised by Mr Hartt as the equivalent of the beds containing *Zaphrentis* and *Phillipsia* on the Kennetcook River, and it can be identified with one of the limestones of Lower Stewiacke.

(*d.*) Brownish or buff-coloured impure limestone, very rich in shells (Windsor Limestone, Hartt)—*Aviculopecten Limestone.* This limestone especially abounds in Lamellibranchiates, particularly species of *Aviculopecten*, *Pteronites*, *Macrodon*, and *Modiola*. *Naticopsis Howi* is also very characteristic. It also contains *Productus cora* (var.), *Terebratula sacculus*, *Rhynchonella Evangelini*, Hartt, a *Leperditia*, and a *Serpula ;* and the little coral *Stenopora exilis* is very common. *Bakevellia antiqua* also occurs in it, and a *Conularia.* The Brachiopods in this bed are small and depauperated, indicating probably shallow and turbid water. This limestone appears to correspond to the shell limestone of Gay's River, near Wordsworth's, that of "Anthony's Nose," Shubenacadie, and the yellow limestone of De Bert River.

(*e.*) Compact gray shelly limestone (Stewiacke Limestone, Hartt), *Productus Limestone.* This is the richest of all the beds in fossils, and contains the greater number of those mentioned in the following lists. More especially it abounds in *Productus cora*, *Athyris subtilita*, *Terebratula sacculus*, *Fenestella Lyelli*, *Macrodon Hardingi*, *Conularia planicostata ;* and it is the special habitat of *Nautilus Avonensis*, and *Orthoceras dolatum*, *O. Vindobonense*, *O. laqueatum*, and *O. perstrictum.* It is the equivalent of the upper or red De Bert limestone, the Admiral's Rock on the Shubenacadie, and the Brookfield shell limestone.

Are these subdivisions of the Windsor limestones, as indicated by Mr Hartt, merely local, or have they a more general value? In writing to Mr Davidson, in 1862, I was inclined to believe that the lithological differences in the limestones are local, and "may have been caused through the limestones having been deposited in limited basins or narrow straits, and probably at a time of much volcanic disturbance," and that the only general distinctions are those between the Lower limestones and the Upper, the former being "darker in colour, more laminated, and less fossiliferous," and characterized by the prevalence of certain species of fossils. Mr Hartt's investigations have so far modified these conclusions, that I am prepared to admit, for the area

of Colchester and Hants at least, a more minute general subdivision. I would still, however, group sections (*a*), (*b*), and (*c*), as the *Lower* series, which I believe can be traced throughout Nova Scotia, and sections (*d*) and (*e*) as the *Upper* series, which is also very generally distributed. To these I would add a third group (*f*), including the Upper Carboniferous marine limestone of Wallace, with *Productus semireticulatus* (?), a small and depauperated form, *Aviculopecten simplex*, *Terebratula sacculus*, and *Cardiomorpha*, sp. Taking this view, the following table will give the distribution of these sub-formations as far as known to me:—

Tabular View of the Subdivisions of the Carboniferous Limestone of Nova Scotia (in descending order).

	Subdivisions.	*Colchester and Hants.*	*Cumberland.*	*Pictou and Antigonish.*	*Cape Breton.*
Upper Coal Formation Series.	(*f*) Upper Marine Limestone		Mackenzie's Mill, Wallace.		
Lower Carboniferous Upper Series.	(*e*) Productus Limestone.	Upper Limestones of Avon R. at Windsor, Stewiacke R., De Bert R., and Brookfield. Admiral's Rock, Shubenacadie.	Minudie, Napan, and Pugwash Limestones.	Limestones near Fish Pools, East R. Upper Limestones, Antigonish.	Limestones of Lennox Passage, Irish Cove, Sydney Harbour, Middle R., and Boulardarie; Upper Limestone, C. Dauphin.
	(*d*) Aviculopecten Limestone.	Yellow Limestone of Windsor and De Bert R., Anthony's Nose, Shubenacadie; Woodworth's Limestone, Gay's River.	Lower Limestone of Pugwash (?)	Streptorhyncus Shale, East R. (?)	Lower Limestone, Irish Cove, etc.
	(*c*) Zaphrentis or Phillipsia Limestone.	Blue Limestones of Windsor, Kennetcook and Cockmegun R.; Steven's Limestone, Lower Stewiacke(?); Lowest Limestone, De Bert R.	It is doubtful if these appear in Cumberland; but they may be looked for in the neighbouring parts of New Brunswick.	Limestones of Ohio R. and Lochaber.	These Limestones probably exist at Mabou, and on the Bras d'Or Lake, in various places.
Lower Carboniferous Lower Series.	(*b*) Crinoidal Limestone.	Crinoidal Limestones of Windsor, near Admiral's Rock and Rose's Plaister Quarry, Shubenacadie, Upper Musquodoboit.		Limestone and Shale of Grant's Bridge, East R., and Forks of East R.	
	(*a*) Spirifer Limestone.	Lower Limestones of Windsor; Lower Gay's R. Limestone, Black Rock, Shubenacadie; Economy Limestone.		Lower or Lithostrotion Limestone of Springville, East R.	Lower Limestone at C. Dauphin (?)

With regard to the second point above referred to, the age of these limestones and their equivalency with those of other countries, it is necessary to relate the history of the question, and then to state the peculiarities of these beds which have caused so various opinions to be entertained in regard to them. The earliest statement as to their age was that of Mr R. Brown, in Haliburton's "Nova Scotia." He correctly regarded the limestones of northern Cumberland as Lower Carboniferous, on the evidence of their stratigraphical position, as underlying the Cumberland Coal-field. At the same time, in the central part of the province, where the relation to the Coal formation was not clear, and the physical aspect of the rocks was peculiar, these beds were assigned to the New Red Sandstone. Messrs Jackson and Alger and Dr Gesner continued to hold this last view, and the latter extended it to the Cumberland beds previously placed in their true position by Mr Brown. Sir William Logan, in 1841, visited Horton Bluff and Windsor, and finding that the beds at the former place, which he supposed to be the Coal measures, were lower than the Windsor limestones, naturally supposed the latter to be of Permian age. Mr Lonsdale, after a hasty examination of the fossils, concurred in this view. Sir Charles Lyell, in his examination of the province in 1843, saw good reason to doubt this; and, with the aid of the writer, explored with care the sections in the East River of Pictou and the Avon. His results were published in his "Travels" in 1845, and were subsequently fully confirmed by more extended observations made by the writer and by Mr R. Brown. The Carboniferous date of these beds is now established on the surest grounds, both stratigraphical and palæontological. In regard to the former, the fact that in the sections at Cape Dauphin, at the East River of Pictou, and in Cumberland, the marine limestones underlie the productive Coal measures is indisputable, and these limestones contain the fossils of the upper beds of the Windsor series. In regard to the fossils, Davidson, the best authority on the subject, affirms them to be Carboniferous; and in so far as the Brachiopods are concerned, many of them identical as to species with those of the British Carboniferous limestone. De Koninck, the celebrated Belgian palæontologist, confirms this view; stating, as quoted by Davidson, that this fauna "completely recalls that of the Carboniferous limestone of Visé in Belgium." Yet it is true that the rocks themselves, the limestones, the red sandstones, the marls, and the gypsums, have much the aspect of Permian rocks, and that the fossils, though Carboniferous, have, in the upper beds especially, an unusual number of forms common to the Carboniferous and Permian; while on the other hand, as has been observed by Mr Hartt, they do

not resemble the so-called Sub-Carboniferous limestones and fossils of the Western States, but are more nearly allied to those upper members of the Carboniferous known in the west as Permo-carboniferous. Dr Newberry and Mr Meek, to whom specimens have been shown by Mr Hartt, were much struck by these differences and resemblances; and the latter suggests the idea that we may here have what M. Barrande would call a "colony" of Permian forms in the Carboniferous age,—a suggestion which contains the germ of the true solution. This same solution, in another form, is also indicated in the following extract from Mr Davidson's paper in reference to the remarkably rich shell limestone of Brookfield:—

"The very remarkable shell-rock above described occurs at Brookfield, a little east of the Shubenacadie River; it was first discovered by the late Mr G. Duncan, and by him made known to Dr Dawson. It is in the line of strike of the Shubenacadie beds, and is doubtless a continuation of them. This rock has such a great general resemblance to certain Permian shelly limestones with which I am acquainted, that, had the specimens been submitted to me without any indication as to their geological age, I should certainly have felt somewhat puzzled to determine whether I had to deal with a Permian or a Carboniferous rock and its fossils; and, indeed, when M. de Verneuil determined these fossils for Sir C. Lyell in 1845, he enumerated, among others, *Terebratula elongata* and *T. sufflata*, Schl., *Spirifera cristata*, Schl., *Avicula antiqua*, Münster, a *Modiola*, a *Littorina*, and one or two other fossils which he considered to be common to both the Permian and the Carboniferous strata. Although I may modify to some extent the lists of species published by Sir C. Lyell and Dr Dawson, I quite coincide with what is stated by the former author, at p. 205 of his 'Travels,' viz., 'That geologists should at first arrive at this result (of considering the rocks in question as the equivalents in age of the Permian of Russia) will surprise no one who is aware how many of the fossils of our Magnesian limestone and Coal resemble each other, or who studies the lists given at p. 218, in which several species both of shells and corals from Nova Scotia, identical or closely allied to well-known Permian or Magnesian limestone forms, are enumerated.'"

I venture to give the explanation of the whole difficulty in the following statements, the illustration of which must be sought in the descriptions of these rocks in other parts of this work:—

(1.) The faunæ of the seas of the Lower Carboniferous, Coal formation, and Permian periods, both in Europe and America, present so great similarities that they may, in a broad view of the subject, be regarded as identical.

(2.) The changes and subdivisions of this fauna are related not merely to lapse of time, but to vicissitudes of physical conditions. At Windsor, for example, the fauna of the *Aviculopecten* bed is manifestly that of a shallower and more sandy sea than that of the *Productus* bed; and further, the change from the fauna of the Lower series to that of the Upper series coincides with the deposition of the great gypsums and gypseous marls. It is the same in the Shubenacadie section.

(3.) It follows that, if the peculiar Permian conditions indicated by the rocks came in earlier in Nova Scotia than in Europe, the character of the fauna might also be changed earlier. In other words, we have both rocks and shells with Permian aspect in the Lower Carboniferous period.

(4.) In accordance with this, it is the Upper series of limestones, and those most nearly related to the gypsums and marls, that have the most Permian aspect. The lower Windsor limestones and those of Economy and Pictou have much more the ordinary Lower Carboniferous character and fossils.

(5.) In the little bed of marine limestone at M'Kenzie's Mill, Wallace, we have an example of the existence of some members of this fauna in the period of the Upper Coal formation, where we have also a greater number of the fossil plants that extend upward from the Coal formation into the Permian; and there is nothing to preclude the supposition, already stated in the preceding chapter, that some of the upper limestones of Colchester and Hants may have been deposited contemporaneously with the Middle Coal formation. At the same time, it must be admitted that this last supposition is not proved, and that the appearances in those places where the Coal measures occur are not in its favour.

(6.) It is evident that the marine fauna of the Lower Carboniferous in Nova Scotia more nearly resembles that of Europe than that of the Western States. This is no doubt connected with the fact that the Atlantic was probably an unobstructed sea basin as now, while the Appalachians already, in part, separated the deep sea faunæ of the Carboniferous seas east and west of them. In the Permo-carboniferous period the connexion may have been more complete, or perhaps the shallow-water species may have at all times been able to migrate. Perhaps, however, there was no migration in the case, but only the recurrence of similar and representative species under similar conditions of existence.

(7.) It must not be overlooked that, as a set-off to the Permian appearance of the fossils of the Lower Carboniferous in Nova Scotia, we have the occurrence of such old forms as *Phillipsia*, *Centronella*,

Conularia, *Strophomena*, *Zaphrentis*, etc., either not found, or rarely found, higher than the Lower Carboniferous in other countries.

It is a matter of regret to me that I have not had time fully to investigate all the facts bearing on this curious question. I would commend it to those who may follow me, to whom that which I have been able to do may at least be of service in guiding their researches.

Descriptive List of Fossils of the Carboniferous Limestone.

PROTOZOA.

Dentalina priscilla, n. sp. (Fig. 82), coll. Hartt, Windsor.—Shell formed of several elongated or short cells, separated from each other externally only by slight constrictions; diameter about 1-40th of an inch. This little shell is very abundant on the surfaces of bed (*b*), Windsor, but always in fragments. I do not feel at all certain as to its affinities, more especially as in the longitudinal section it does not show true septal plates, but only slight constrictions at the nodes.

Fig. 82.—*Dentalina; nat. size and magnified.*

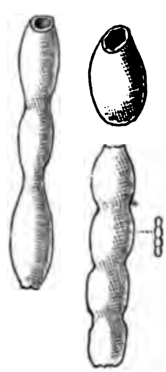
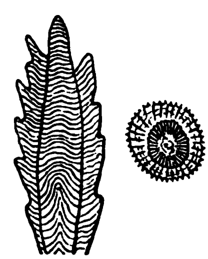


Fig. 83.—*Lithostrotion Pictoense. Longitudinal and Transverse Sections.*



RADIATA.

Lithostrotion Pictoense, Billings (Fig. 83), coll. J. W. D., East River, Pictou.—This fine coral is characteristic of a thick bed of limestone at Lime Brook, East River. The following description has been kindly prepared by Mr Billings:—

"Corallum fasciculate, dendroid. The corallites are elongate, cylindro-turbinate, the young individuals springing from the sides of the adult at various heights, rapidly attaining the full size; at first slightly divergent, then parallel, and usually in contact with each other, or nearly so. They seem to be covered by a thin compact epitheca, and

to be strongly and irregularly annulated. The greatest diameter observed is seven lines, but it is probable that the average is about six lines. In a transverse polished section, six lines across, the inner area is three lines in diameter, and shows twenty-four septa, which do not penetrate more than half a line. The columella is obscurely indicated in the centre. The external area is one and a half lines in width, with the inner side of the epitheca crenulated by about forty-eight septa, one half of which can be indistinctly traced across to the inner wall. In the longitudinal section the external area exhibits a tissue of imbricating meniscoid cells, inclining upwards and outwards, their upper sides convex, lower sides with one or two concavities, due to the convexity of the cells below them. The average size of these cells is one line in length by half that in width; there are many smaller and larger ones. In the inner area the transverse diaphragms or tabulæ are thin and crowded, apparently four or five, on an average, in one line; they seem to be much elevated in the centre, and also sometimes turned upwards at their junction with the inner wall. The axis is indistinctly indicated.

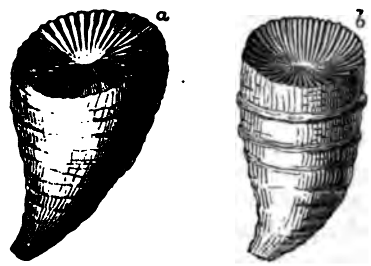
"The only species with which this need be compared is *L. affine* (Fleming), of the Carboniferous limestone of England and Ireland. According to the description and figures of Edwards and Haime, that species has the corallites about five or six lines in diameter, and grouped together as they are in this; but they are not annulated exteriorly, except by small wrinkles; the inner wall is not so distinctly defined; the inner area narrower, and the columella more compact and perfectly developed. It has also thirty or thirty-two principal septa, while in this there are only about twenty-four.

"The two specimens on which the above description is founded are imbedded in compact limestone, and although in the polished sections their internal characters are well defined, yet in a large collection individuals might be found to connect it to *L. affine.* It is a closely allied species, but I think distinct."

Zaphrentis Minas, n. sp. (Fig 84, *a*), collected by Professor How at Kennetcook.—Corallum conical, slightly curved. Calice circular, thin-edged, rather shallow; septal fossula narrow, extending from the centre to the concave side. Principal septa about thirty-two. Tabulæ irregular. Epitheca thin, marked externally with longitudinal striæ and coarse scaly ridges, especially near the upper part. My longest specimen is two inches in length, and has probably lost an inch of the lower part. It is one inch in diameter. The same species occurs at Cockmegun River and Stewiacke; and small specimens, possibly

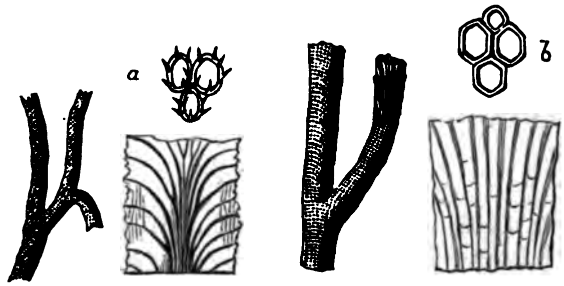
of the same species, at West River, Pictou. In old specimens the sides become very rugose, and the coral becomes narrowed at the top.

Fig. 84.—(*a*) *Zaphrentis Minas*; (*b*) *Cyathophyllum Billingsi*.



Cyathophyllum Billingsi, n. sp. (Fig. 84, *b*).—Corallum circular in cross section, short, curved at the base. Unbroken surface with vertical low ribs and strong transverse plates; broken surface with square reticulation. Calice shallow, with about forty equal, straight septa. Coll. Hartt, Lower Stewiacke.

Fig. 85.—(*a*) *Stenopora exilis*; (*b*) *Chaetetes tumidus*.



Stenopora exilis, n. sp. (Fig 85, *a*), coll. J. W. D. and C. F. Hartt, Shubenacadie, Windsor, Stewiacke.—This is the coral, or one of the corals, designated as *Ceriopora spongites* in my former edition, and it is scarcely distinguishable by external characters from *Calampora Macrothii*, of King's Permian fossils; but it wants entirely the generic characters of *Calamopora*, and therefore I describe it here as a distinct species, though by no means affirming that it may not be identical with some of the species of little branching Carboniferous corals about which so much confusion exists. It presents slender cylindrical branches, ramifying irregularly and sometimes anastmosing, from half a line to a line in diameter, and covered with minute contiguous hexagonal cells with small spines or papillæ on their separating walls.

In a longitudinal section the cells are seen to rise vertically, and then suddenly curve to the surface, increasing at the same time in diameter, and having near the aperture a few thin transverse plates. It is perhaps worthy of inquiry whether this may not have been a Polyzoan allied to *Helopora*. It is very abundant at Windsor and on the Shubenacadie, subdivision (*d*).

Chaetetes tumidus (Fig. 85, *b*), Edwards and Haime.—I refer to this common Carboniferous species, a coral very abundant at Stewiacke, and occurring also at Windsor and in Cape Breton, and which a careless observer might readily confound with the preceding. It is, like it, a slender branching coral, but often more robust, and sometimes presenting even rounded or papillose masses; and in the longitudinal section its tubes do not curve suddenly outwards, but turn from the centre with a gentle sweep toward the surface. Externally also it has no spines on the separating walls. Though I suspect that the synonymy given by Edwards and Haime includes several species, I feel certain that the present is one of them, and I have no hesitation more particularly in identifying it with *Favosites scabra* of De Koninck. All these small branching corals of the Palæozoic rocks require a thorough microscopical examination.

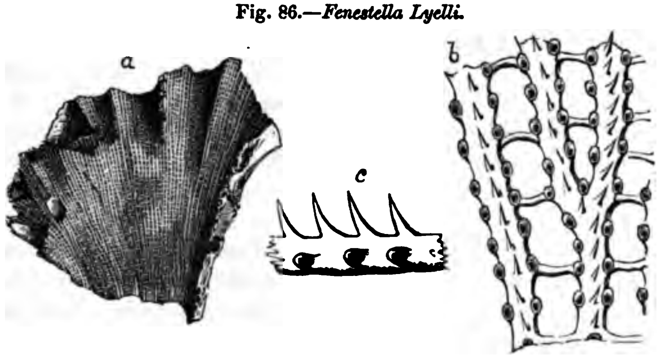
Crinoidea.—Though some beds of limestone on the Shubenacadie at Windsor, and on the East River of Pictou, are full of crinoidal fragments, more particularly the joints of the stems, no specimens sufficiently complete for description have yet been found.

MOLLUSCA.

Polyzoa.

Fenestella Lyelli, n. sp. (Fig. 86), coll. J. W. D., Windsor; coll. Hartt, Stewiacke.—This beautiful species is very characteristic of

Fig. 86.—*Fenestella Lyelli.*



(*a*) Natural size. (*b*) Portion enlarged. (*c*) Cells and spines in profile.

one of the limestones of the Windsor series, and is, I think, certainly new and undescribed. The non-poriferous side has thick parallel bifurcating ribs, with rounded surfaces finely striated longitudinally, connected by much thinner and rounded cross bars, enclosing oval fenestrules. The poriferous side has the bars angular above, and with a central carina, bearing a row of small tubercles, which in the best specimens are seen to bear delicate spines. The pores are in two rows at the sides of the ribs. Its nearest allies are *F. reteformis*, Schlot., and *F. carinata*, M'Coy, but it differs materially from both, more especially in its characteristic spines.

Fenestella, another species, coll. J. W. D., Stewiacke, with two rows of large contiguous pores. Resembles *F. Morrisii*, M'Coy, but has the pores closer to each other.

Fenestella with larger fenestrules, not determinable. Coll. J. W. D., West River, Pictou.

Berenicea, Lamx.—Two species of encrusting Polyzoa occur on shells in Mr Hartt's collections from Windsor. They may, in the meantime, be referred to this genus, but are not determinable.

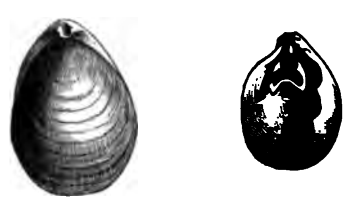
Brachiopoda.

The following descriptions of the Brachiopods of the Carboniferous limestones of Nova Scotia are extracted from Mr Davidson's paper above referred to, and the figures are from his drawings :—

" *Terebratula sacculus*, Martin, sp., 1809, and varieties (Fig. 87).

" *Terebratula elongata* and *T. sufflata*, De Verneuil, in Sir C. Lyell's 'Travels in North America,' vol. ii., p. 220, 1845; and in Dawson's 'Acadian Geology,' p. 219 (Fig. 27), 1855.

Fig. 87.—*Terebratula sacculus*, Martin; *and interior, showing loop.*



" All the *Terebratulæ* from the Lower Carboniferous strata of Nova Scotia that have been forwarded to me by Dr Dawson, as well as those brought from that country by Sir C. Lyell, are variable in shape, but are evidently referable to a single species. M. de Verneuil has identified this shell with Schlotheim's *T. elongata*, and mentions that

a 'gibbous variety of the preceding one' is referable to *T. sufflata* of the same author.

"During a lengthened examination of *T. hastata* and *T. sacculus* from the Carboniferous rocks of Great Britain, as well as of *T. elongata* and *T. sufflata* from the Permian strata of the same kingdom, I was led to the conclusion that the specific identity of *T. sacculus* and *T. sufflata* was clearly established; and, when treating of the Carboniferous *T. hastata* and of the Permian *T. elongata*, I observed that, although it was an unquestionable fact that some specimens of these two so-called species could not be distinguished, more difference is shown between the greater number of *T. hastata* and *T. elongata*, and that the strong resemblance appeared to be the exception. It must also be allowed that it is often impossible to distinguish certain examples of *T. sacculus* and of *T. hastata*, which forms appear to merge the one into the other, and that the same may be said sometimes with reference to *T. sufflata* and *T. elongata*. All this proves how intimately connected are the British forms of Carboniferous and Permian *Terebratulæ*.

"But to return to the Nova-Scotian specimens, I could not perceive in any of them the wide and gradually depressed or shallow sinus, which, in the larger valve of all well-shaped examples of *T. elongata*, commences towards the middle of the valve and extends to the front, and which produces in the frontal margin a convex curve. In nearly every specimen the ventral valve is uniformly convex or but very slightly depressed near the front, as is the case with the larger number of *T. sacculus* and of its synonym *T. sufflata*. I think, therefore, that it will be perhaps preferable to refer the Nova-Scotian *Terebratulæ* to Martin's *T. sacculus;* and in this view I am supported by Professor De Koninck, notwithstanding some examples may resemble certain specimens of *T. elongata*, *T. fusiformis* (Vern.), or *T. hastata*. The largest specimen I have seen was not quite an inch in length, and the greater number were much smaller. The interior, with its perfect, short, simple loop, is often found, and is exactly similar to the one we find in Martin's species. Sir C. Lyell mentions that he obtained this shell at Windsor, Brookfield, Shubenacadie, Gay's River, De Bert River, Middle River, and Cape Breton. Dr Dawson obtained it in the same localities, to which he has added Pugwash, East River of Pictou, Lennox Passage, etc.

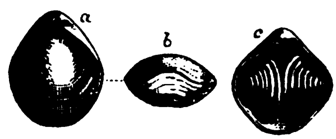
"*Athyris subtilita*, Hall, 1852 (Fig. 88, *a*, *b*, *c*).

"*Athyris subtilita*, in Howard Stansbury's 'Exploration of the Valley of the Salt Lake of Utah,' p. 409, pl. 2 (figs. 1, 2).

"The Nova-Scotian specimens all appear to be small in size, but are

exactly similar (except in dimensions) to those found in other parts of America and Europe. The spiral processes are often preserved.

Fig. 88 (*a, b*).—*Athyris subtilita*, Hall; (*c*) *interior, showing spires.*



"This shell occurs by millions in the Lower Carboniferous limestone of Shubenacadie, Brookfield, etc.

"*Spiriferæ.*—The four so termed species referred to in the lists given by Sir C. Lyell and Dr Dawson appear to belong to two, or at most three (?) species.

"*Spirifera glabra*, Martin, sp. (Fig. 89).

"*Conchyliolithus Anomites glaber*, Martin, Petrif. Derb., pl. 48 (figs. 9, 10), 1809.

"*Spirifer glaber*, De Verneuil, in Sir C. Lyell's 'Travels in North America,' vol. ii., p. 221, 1845, and in Dawson's 'Acadian Geology,' p. 376, 1855.

Fig. 89.—*Spirifera glabra*, Martin.

"This appears to be a common fossil in the Lower Carboniferous limestone of Nova Scotia. It is identical in character with those found in Great Britain; one example brought home by Sir C. Lyell measured 13 lines in length by about 17 in breadth.

"It occurs at East River of Pictou, Mabou, Cape Breton, Windsor, Brookfield, Merigomish, etc.

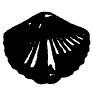
"*Spiriferina cristata*, Schlotheim (Fig. 90).

"*Spirifer octoplicatus*, Sow., Min. Couch. pl. 562 (figs. 2, 3, 4); Dav. Mon. Carb. Brach, p. 38, pl. 7 (figs. 37, 47).

"At p. 221 of his 'Travels,' Sir C. Lyell mentions *Spirifer cristatus*, Schl., *Sp. minimus*, Sow., and *Sp. octoplicatus*, Sow., as having been found in the Lower Carboniferous limestone of Nova Scotia; but it is probable that at least two of the shells so termed—namely, *Sp. cristatus* and *Sp. octoplicatus*, are referable to a single species. The Nova-Scotian specimens of the shell under notice are all very small, none of those that have come under my notice exceeding four lines in length by five in width; they exactly resemble some specimens of the same species found in the Carboniferous shales of Capel Rig, East Kilbride, Scotland.

"Sir C. Lyell mentions having found this shell at Windsor, Brookfield, Shubenacadie, and De Bert River, in Nova Scotia; and Dr Dawson adds East River, but that it is nowhere so plentiful as in the shell conglomerate of Brookfield.

Fig. 90.—*Spirifer cristata*, Schlotheim. Fig. 91.—*Spirifer acuticostata*, De Koninck.



"*Spirifer acuticostata*, De Koninck (Fig. 91).

"*Spirifer acuticostatus*, De Koninck, 'Description des Animaux Fossiles qui se trouvent dans le Terrain Carbonifère de la Belgique,' p. 265, pl. 17, fig. 6.

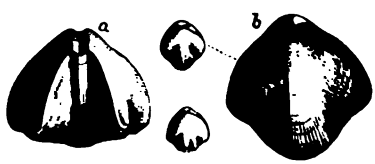
"Shell small and transversely oval; valves convex, and ornamented with from twelve to fourteen small angular ribs. The mesial fold is comparatively wide, flattened, and longitudinally grooved along the middle. The sinus in the ventral valve has a small median angular rib, which commences at about the middle of the valve and extends to the front. Beak small, incurved; area triangular and of moderate dimensions. Length four lines, width five lines, depth three lines.

"Upon sending a proof of the plate illustrating this paper to Professor De Koninck, he wrote back that two of my figures were referable to *Sp. acuticostatus*; and, except in size, they certainly resemble those given by the distinguished Belgian Professor. It must, however, be remembered that in some specimens of *Sp. cristatus*, or of its Carboniferous representative, *Sp. octoplicatus*, the mesial fold is flattened along its middle, and even possesses in some cases a shallow groove along its centre, as seen in De Koninck's *Sp. acuticostatus*. All these modifications in British specimens have been described and illustrated at pages 38 and 226 of my 'Monograph of British Carboniferous Brachiopoda.'

"This small shell is very abundant in the shell limestone of Brookfield, Shubenacadie, and in some other localities in Nova Scotia, where it is always associated with *Sp. cristatus*, of which it may perhaps after all be no more than a modification.

"*Camarophoria and Rhynchonella.*—The specimens referable to these genera sent me by Dr Dawson, as well as those brought to England by Sir C. Lyell, are generally very small, and not in all cases sufficiently complete to warrant a satisfactory determination. I have, however, carefully represented the principal forms.

Fig. 92 (*a*).—*Camerophoria globulina*, Phillips; *nat. size and magnified; (b) variety of the same.*

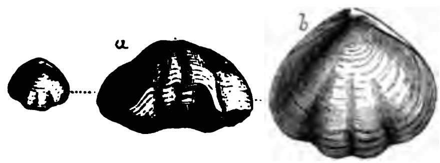


"*Camarophoria* (?) *globulina* (?), Phillips (Fig 92, *a*, *b*).
"*Terebratula globulina*, Phillips, Encycl. Metr., vol. iv., article 'Geology,' pl. 3, fig. 3, 1834.
"*Terebratula rhomboidea*, Phillips, Geol. Yorksh., vol. ii., p. 222, pl. 12, figs. 18, 20, 1836.
"*Hemithyris longa*, M'Coy, British Pal. Foss., p. 440, pl. 3, D., fig. 24, 1855.

"Of this very small shell I have been able to examine only three specimens; but it is stated to be abundant in a yellow arenaceous limestone at De Bert River, where, according to Dr Dawson's experience, it is always small. I have also felt somewhat puzzled in the determination of this fossil; but, after having consulted Professor De Koninck, I concluded to refer the specimens to the same species, notwithstanding the apparent difference they present. Professor De Koninck referred one of them to *T. rhomboidea*, Phillips, which is a synonyme of *Camarophoria globulina;* and after minutely comparing the Nova-Scotian specimens with the Carboniferous and Permian types, I could perceive no difference sufficient to warrant the creation of a new species. The three specimens were exactly of the same size, namely, three lines in length by three in width, and two and a half in depth. The uncertainty which both Professor De Koninck and myself have experienced refers to a specimen which much resembles, in miniature, a form of *Rhynchonella acuminata;* but when we remember

that Phillips himself figures a specimen of his *Terebratula rhomboidea* with a simple mesial fold, we need not be surprised to find the same peculiarity in one of those from Nova Scotia. Indeed, after carefully examining the three examples forwarded by Dr Dawson, I cannot bring myself to believe that they should be specifically separated. It is well known that the same peculiarity occurs with *Rhynchonella acuminata;* and any one who examines plates 20 and 21 of my 'Monograph of British Carboniferous Brachiopoda' must feel surprised at the immense variability of which some species are susceptible.

Fig. 93.—*Rhynchonella Dawsoniana*, Davidson; *nat. size and magnified.*



"*Rhynchonella Dawsoniana*, n. sp. (Fig. 93, *a*, *b*).

"Shell very small, almost circular, a little wider than long; dorsal valve moderately and uniformly convex to about half its length from the umbone, at which point a very slightly elevated and flattened mesial fold begins to rise, and extends to the front; the surface of the shell is also either almost entirely smooth or ornamented with from eight to twelve slightly marked ribs. The ventral valve is gently convex, with a wide sinus; beak small and incurved. Length three and a half lines, width four lines, depth two and a half lines.

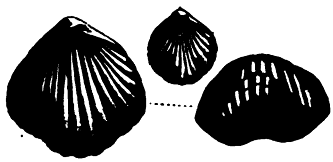
"This small species does not appear to be rare in a black Lower Carboniferous limestone at Lennox Passage, and is not unlike, except in size, certain examples of M. de Verneuil's *Terebratula superstes;* but this last-named Permian shell belongs to the genus *Camarophoria*, while the one under description belongs to *Rhynchonella*. I have compared it with a number of equally small young examples of *Rhynchonella pugnus*, from which it appears to differ.

"*Rhynchonella Acadiensis*, n. sp. (Fig. 94).

"Shell small, obscurely rhomboidal, about as wide as long; dorsal valve rather more convex than the ventral, and presenting, when viewed in profile, a regular curve. The mesial fold commences towards the middle of the valve, while the surface is ornamented with twelve or thirteen small radiating ribs, of which four or five occupy the surface of the fold. The sinus in the ventral valve is of moderate depth, and the surface is ornamented as in the dorsal valve. The

beak is gently incurved, and exhibits a small circular foramen under its angular extremity. Length five lines, width five lines, depth three lines.

Fig. 94.—*Rhynchonella Acadiensis*, Davidson; *nat. size and magnified.*



"Of this shell I have seen but two specimens, which I detached from a lump of the Brookfield shell-limestone, and of which one exhibited the two curved internal lamellæ characteristic of the genus *Rhynchonella*. It is quite distinct from young shells of *Rhynchonella pugnus* and *R. pleurodon*. In the last-named species the ribs that adorn the lateral portions of the dorsal valve are very much curved, while those of the ventral are nearly straight, with their extremities bent upwards; in addition to which, the ribs begin to be longitudinally grooved along their median portion at some distance from the margin. None of these characters are observable in the small *Rhynchonella* under description.

"*Rhynchonella*, sp.—Upon some fragments of Lower Carboniferous limestone brought from Nova Scotia by Sir C. Lyell are several imperfect, undeterminable valves of a *Rhynchonella*, which differs from the preceding species by its size, as well as by the number of its small radiating ribs. Of these last I have counted as many as thirty-five or forty upon each valve. In size it appears to have measured about seven or eight lines in length by nine in width. I abstain from proposing for it a specific denomination, as the material is so imperfect. The specimen belongs to the Geological Society.

"*Rhynchonella pugnus* (?), Martin, sp., Petrif. Derb., tab. 22, figs. 4, 5, 1809.

"Two or three very small specimens, received from Dr Dawson after my plate had been completed, much resemble certain young shells of Martin's species; they are derived from the Lower Carboniferous limestone of Windsor and East River.

"*Strophomena analoga*, Phillips (Fig. 95).

"*Producta analoga*, Phillips, Geol. Yorksh., vol. ii. pl. 7, fig. 10, 1836.

"Upon a specimen of dark, impure limestone brought from Nova

Scotia by Sir C. Lyell, and now in the Society's Museum, I found a well-characterized example of this species, which in Sir C. Lyell's list had been confounded with *Productus Martini.*

Fig. 95.—*Strophomena analoga*, Phillips.

Fig. 96.—*Streptorhynchus crenistria*, Phillips, *and sculpture magnified.*

"*Streptorhynchus crenistria*, Phillips (Fig. 96).

"Several crushed valves, referable to this species, occur on a specimen of Carboniferous shale from East River, Pictou,* for which I am indebted to Dr Dawson. These valves exactly resemble certain small specimens found in several British Carboniferous shales. Their surfaces are covered with numerous radiating raised striæ, with a smaller rib between the larger ones, the whole being closely intersected by fine concentric lines, thus giving to the longitudinal ribs a crenulated appearance. Professor De Koninck coincides in my identification.

"*Productus.*—Although Sir C. Lyell and Dr Dawson mention seven species of this genus as having been found in the Lower Carboniferous rocks of Nova Scotia, all these, as well as the specimens I have been able to examine, can be referred to two species only, namely, *P. semireticulatus* and *P. cora;* and I may mention that Prof. De Koninck coincides in this view.

"*Productus semireticulatus*, Martin (Fig. 97).

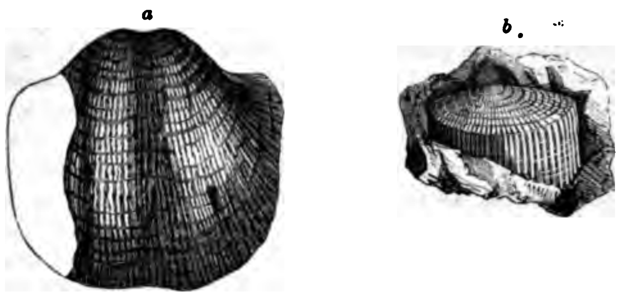
"*Anomites semireticulatus*, Martin, Petrif. Derb., pl. 32, figs. 1, 2, and pl. 33, fig. 4, 1809.

"This species is so well known that all I shall require to state is, that the Nova-Scotian specimens are exactly similar to those found in Europe. *Producta Martini*, *P. concinna*, *P. antiquata*, *P. Scotica*, mentioned by Sir C. Lyell at p. 220 (vol. ii.) of his 'Travels in America,' as well as by Dr Dawson in various pages of his 'Acadian Geology,' belong to a single species, namely, *Productus semireticulatus*, Sow. The '*P. spinosa*, Sow. (?) var. of *P. Martini*,' of Sir C. Lyell's

* The locality is incorrectly given Shubenacadie in the paper quoted.

list, belongs likewise to the species under description; but *P. spinosa*, Sow., specimens of which I have not seen from Nova Scotia, is a distinct species. Sir C. Lyell mentions Windsor, Brookfield, Shubenacadie, East River, De Bert River, and Minudie. Dr Dawson states that the shell is found almost everywhere—at Pugwash, near Amherst, Boulardarie, Cape Breton, Horton Bluff, Gay's River, etc.

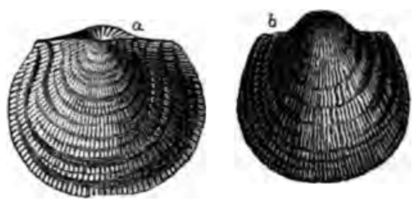
Fig. 97.—*Productus semireticulatus*.—Martin.



(*a*) Ventral valve. (*b*) Small specimen showing dorsal valve.

"The largest specimen measured one inch and a half in length by about the same in width. The variety *Martini* is also found in the same locality.

Fig. 98.—*Productus cora*.—D'Orbigny.



(*a*) Dorsal, and (*b*) ventral valve.

"*Productus cora*, D'Orbigny, 1842 (Fig. 98).

"*Productus cora*, D'Orbigny, 'Paléont. du Voyage dans l'Amérique Mérid.,' p. 55, pl. 5, figs. 8, 9, 10, 1842.

"*P. comoides* and *P. Scoticus*, De Kon. 1843 (not of Sow.)

"*Producta corrugata*, M'Coy, 'Synopsis of the Carb. Limest. Fossils of Ireland,' pl. 26, fig. 13, 1844.

"*P. Lyelli*, De Verneuil, Sir Charles Lyell's 'Travels in North America,' vol. ii. p. 221, 1845.

"*P. tenuistriata* and *P. Neffedievi*, De Vern., 'Russia and the Ural Mountains,' 1845.

"*P. cora*, De Koninck, 'Mon. du Genre *Productus*,' pl. 4, fig. 1, 1847.

"*P. pileiformis*, M'Chesney, 'Descr. of New Species of Fossils from the Palæozoic Rocks of the Western States of America,' p. 40, 1849.

"*P. Lyelli*, Dawson, 'Acadian Geology,' p. 219, fig. 9, 1855.

"*P. Cora*, Dav., 'Mon. Carb. Brach.,' pl. 36. fig. 4, pl. 42, fig. 9, 1861.

"After a very careful examination of nine or ten specimens of *P. Lyelli* from the Lower Carboniferous limestone of Nova Scotia, I have reluctantly been obliged to place M. de Verneuil's species among the synonymes of *P. cora*, the latter name (as may be seen by the list of synonymes above given) claiming three years' priority. All the Nova-Scotian specimens I have been able to examine were small, not exceeding about 11 lines in length by some 12 or 13 in width. But it must be remembered that, as a general rule, the Nova-Scotian species and specimens, although adult, are small, and in this respect are exactly similar to those we find in Scotland. The surface is covered with numerous longitudinal, straight, or slightly flexuous, narrow, thread-like, rounded striæ, with sulci, or interspaces, of rather less width; smaller striæ are also here and there intercalated between the larger ones. The ribs are also regularly and closely crossed by small concentric lines.

"*P. cora* is a widely spread Carboniferous species, having been found in many parts of America, India, Europe, etc.

"Sir C. Lyell found this shell at Windsor, Horton Bluff, Shubenacadie, Gay's River, Minudie, and Cape Breton, in Nova Scotia. Dr Dawson states that it occurs almost everywhere—at Pugwash, on the eastern coast of Cumberland, at Lennox Passage, M'Kenzie's Mill, at the eastern extremity of Wallace Harbour, etc."

Mr Hartt has kindly furnished the following descriptions and specimens of additional species of *Brachiopoda*:—

Rhynchonella Ida, Hartt, Bed A, Windsor. Coll. C. F. Hartt.—Shell elliptical, transverse, wider than long, rounded on the sides, truncate in front, angular at the umbo, inequivalve. Dorsal valve large, more inflected than the ventral, moderately arched, slightly depressed in umbonal region, with a wide, slightly elevated mesial fold.

Ventral valve less arched than dorsal, highest in the middle, from which point it curves regularly to the umbo and posterior margin. Umbo sharp, angle made by sides of valve at the umbo a right angle. Outline of valve a right angled triangle rounded at the acute angle. Sides of valve depressed. A shallow sinus corresponds to the fold of the dorsal valve. It originates near the middle of the valve. Umbo more or less strongly recurved. Foramen small, triangular. Deltidium

in two narrow pieces. False hinge area narrow. Surface marked by 16—21 large elevated rounded radiating plaits, each one of which increases in size from the umbo to the margin. They also increase in size from the sides to the sinus or fold, on the side of which the largest one occurs. The sinus is occupied by 3—4 small plaits of equal size. Length, 5-16th inch; breadth, 9-16th inch; thickness, 4-16th inch.

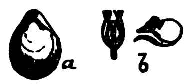
The above is believed to be identical with a species referred to by Mr Davidson, as represented in the collections submitted to him, by only one imperfect specimen, and delineated at fig. 15 of his paper.

Rhynchonella Evangelina, Hartt.—Shell minute, length about 5-16ths of an inch, length and breadth about equal, greatest breadth at middle. In dorsal aspect square, the umbo forming an angle, the three others rounded, in umbonal aspect triangular. Dorsal valve very much larger, and more inflated than the ventral; would be semi-globose but for a prominent mesial fold, which originates at or about the middle of the valve, and seems growing higher and higher to the posterior margin, beyond which it projects, forming one of the angles of the square. In profile the fold describes a more or less regular quadrant, the posterior part of which becomes parallel, or nearly so, with the longitudinal axis of the shell. The summit of the fold bears two or three angular plaits, separated by a deep groove or grooves, which originate with the fold, and grow deeper as the latter becomes more elevated. Fold with steep flattened sloping sides; occasionally these bear minor supplementary grooves. On each side of the shell are two or three large radiating angular plaits, originating about half-way from the umbo to the margin, in running towards which they increase in size, describing in profile a regular curve. As the valve has a more or less steep slope from the fold to the sides of the valve, these plaits have a narrow slope on the inner and a long one on the outer side, so as to give to them an imbricated appearance. Ventral valve depressed forward, with a deep, wide mesial sinus, beginning near the umbo, and corresponding to the mesial fold of the opposite valve. Sinus occupied by prominent plaits corresponding to the grooves on the summit of the fold. On the sides of the shell, plaits, corresponding in like manner to these grooves of the opposite valve. Where there are two grooves on the fold, the two corresponding ventral plaits are formed near the anterior part of the sinus by the bifurcation of a single plait. Umbo angular, sharp-pointed, and quite strongly recurved. Foramen narrow, triangular, with deltidium in two pieces. Interior of dorsal valve with the two short curved processes so characteristic of the apophysary system of Rhynchonella.

This is probably the species referred by Mr Davidson, with doubt, to *R. pugnus* (?) in his paper above referred to.

Centronella Anna, Hartt (Fig. 99).—Shell orbicular, lenticular, equilateral, inequivalve, the dorsal (ventral, *Hall*) valve being considerably more arched than the ventral (dorsal, *Hall*). *Dorso-ventral* diameter about half that of the width of shell—length about a quarter of an inch.

Fig. 99.—*Centronella Anna*, Hartt.



(*a*) Shell natural size. (*b*) Internal loop.

Ventral valve with lamellæ which take their origin near together. These lamellæ separate slightly from one another until they are inclined to one another at an angle from 30°–45°, when they curve towards the mesial line, and meeting at a very acute angle, are prolonged backwards in a pointed arch to three-quarters—four-fifths the length of the shell, the width of the arch being approximately one-half its length. The planes of the lamellæ are at first parallel, but their dorsal edges soon become moderately inclined outward. The lateral bands are not only bent toward the mesial line, but they are strongly curved, with the convexity towards the ventral valve, the curve being slightly greater than that of the valve. This loop supports on the dorsal side a thin plate, whose plane coincides with the dorso-ventral and antero-posterior diameter of shell, and a thin plate extends from the apex of the arch forward (backward *auct.*) for about two-thirds its length. This plate seems to be of uniform thickness throughout. At the point of the arch the supporting lamellæ are exceedingly slender. Tracing them anteriorly, they are seen running along the ventral border of the mesial plate, on each side, like a raised line. Increasing in width, they separate themselves more and more along the dorsal margin from the mesial plate, to whose ventral border they are attached for its whole length. The plate has an outline similar to that of a transverse section of a biconvex lens whose diameter is twice its thickness, but in both the loops under examination there is on the dorsal edge a notch which appears to be organic, and to correspond to that of the loop of *Centronella Julia*, Billings.

The mode of attachment of the mesial plate with the lateral bands is very well shown in my specimens. Professor Hall has called attention to the strong resemblance between the loops of *Centronella* and *Rensselaria*, but there is a much greater resemblance between the

loops of my Carboniferous species and that of *Rensselaria*. This species is not uncommon in the Windsor limestones at Windsor, where it is usually so preserved as to show the interior with loop. The shell appears to be very fragile, and specimens showing the external characters are rare; at least I do not possess an example. There is a species of *Centronella* occurring in the Stewiacke limestones at Windsor and Stewiacke which may be identical with this, but I have no good specimens for comparison.

Centronella, as far as I am aware, has been found only in Devonian rocks. Its occurrence in the Carboniferous limestones of Acadia, with forms so Permian in character, is very interesting.

Spirifera striata, Martin, coll. Hartt, from Windsor.—A ventral valve, 1½ inch in breadth, has been found by Mr Hartt in the Windsor limestones. It does not appear to differ from specimens of the well-known British *S. striata* in my collection. It is the largest *Spirifer* yet found in Nova Scotia, and helps to redeem our Lower Carboniferous shells from the charge of prevailing smallness.

Crania.—A valve attached to a specimen of *Productus cora* in the collection of Mr Hartt from Windsor. It is too obscure to be determined or named.

Lamellibranchiata.

Modiola Pooli, n. sp. (Fig. 100), coll. J. W. D. and H. Poole, Shubenacadie, Windsor, Irish Cove, C. B.—Tumid, elongate; nearly cylindrical, but more tumid in front; surface with delicate lines of growth.

Fig. 100.—*Modiola Pooli* (*cast*).

Fig. 101.—*Pteronites Gayensis*.

Modiola Avonia, n. sp., coll. Hartt, Windsor.—A regularly ovate, smooth (?) species, known to me only by casts which abound in bed (*d*).

Pteronites Gayensis, n. sp. (Fig. 101), coll. J. W. D., Gay's River, Chester, similar in general form to *P. latus*, M'Coy. Beaks prominent, pointed; hinge-line straight, reflected, anterior extremity very short, posterior part flattening and widening with a regular curve to the broad rounded posterior extremity. Surface with rounded concentric wrinkles.

Bakevellia antiqua, Munst., coll. J. W. D., Gay's River.—A very characteristic and abundant shell, with the last species, and also in the

Aviculopecten limestone at Windsor. The elongated form *Cerato-phaga* is also present.

Macrodon Hardingi, n. sp. (Fig. 102), coll. J. W. D. and Hartt, from Windsor, especially in bed (*e*), where it is very abundant. Hinge-line nearly straight, with the short cardinal teeth and long narrow posterior teeth characteristic of the genus. Length about twice the depth, but variable; beak one fourth of the length from the front, which is pointed, and descends with a regular curve to the straightish

Fig. 102.—*Macrodon Hardingi.*

(*a*) Cast. (*b*) Outer surface. (*c*) Sculpture magnified.

or slightly incurved ventral margin. Posterior extremity truncated, almost vertically, angular above, slightly rounded below. In old specimens very tumid at the beaks, so that the thickness sometimes exceeds the breadth. The shell, which seems to have been thick, is usually represented by casts of the interior, which are smooth, sometimes with deep marks of the muscular impressions and a trace of a rib proceeding from the front of the beak; but when the outer surface is preserved, it is seen to be covered with regular squamous concentric folds, fringed at the edges with delicate radiating lines. This beautiful shell, most characteristic of the upper stages of the Lower Carboniferous limestones, is allied to *Byssoarea reticulata*, M'Coy, of the Irish Carboniferous, and to *Arca M'Coyana* and *anatina*, De Koninck, of Belgium, also to *Byssoarea tumida* of the Permian,—but it is decidedly a new species. The specimens figured are of medium size. The largest are one and a quarter inch long and seven lines thick at the beaks.

Macrodon curtus, n. sp., coll. J. W. D., Windsor, etc., with the preceding.—This shell differs from the last in the following particulars:—It is much shorter, broad opposite the beaks, and narrowing posteriorly, and covered with irregular lines of growth. As I have not seen the teeth, it may belong to a different genus. On the other hand, it may be a depauperated variety of the preceding, but I have no connecting forms.

Macrodon (?) *Shubenacadiensis*, n. sp. (Fig. 103), coll. J. W. D., Shubenacadie.—Short and ovate, hinge-line straight, umbo one-third of the distance from front. Posterior extremity broadly and regularly

rounded. Anterior end gibbous and narrow. Very common at Shubenacadie and Windsor, also in Cape Breton. Its genus is uncertain.

Macrodon.—A fourth species is known to me only by a few casts of the interior. It is more elongated than *M. Hardingi*, and is rounded at the posterior extremity. Its external surface is unknown.

Fig. 103.—*Macrodon Shubenacadiensis* (*cast*).

Fig. 104.—*Edmondia Harttii.*

Edmondia Harttii, n. sp. (Fig. 104), coll. Hartt, Windsor.—Transversely oblong, flattened, regularly rounded posteriorly, marked with very coarse concentric lines of growth. Resembles *E. sulcata*, Phil., of the English Carboniferous limestone, but is more elongated and rounded posteriorly. Length one inch six-tenths, breadth eight-tenths.

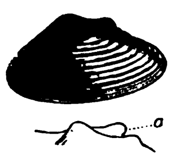


Fig. 105.—*Edmondia anomala.*

(*a*) Outline of hinge-plate.

Fig. 106.—*Cypricardia insecta.*

Edmondia anomala, n. sp. (Fig. 105), coll. Hartt, Windsor.—Transversely elongate; anteriorly elongate and pointed; posteriorly descending abruptly from a line passing backward from the tumid beaks to the lower side of the posterior margin. Surface marked in the central part with regular concentric folds. Fulcral plate extending more than half-way from the beak to the posterior end, widening and abruptly rounded posteriorly. Resembles a *Sedgwickia* in form, but differs in the hinge.

Cypricardia insecta, n. sp. (Fig. 106), coll. Hartt, Windsor, bed (*a*).—Transversely oblong. Thrice as wide as long, anterior end very short, posterior somewhat keeled. Hinge-line rather more than half as long as the shell, posterior margin rounded. Surface covered with strong concentric folds. Length, one inch nine-tenths.

Pleurophorus quadricostatus n. sp. (Fig. 107), coll. Hartt, Stewiacke. —Shell elongate, beaks near anterior end. Hinge-line nearly straight, central margin with a fold and sinus under the beak, and curving thence to the rounded posterior end; four obscure radiating ridges diverging from the beak to the posterior margin, crossed by low concentric undulations. Length, five lines. Bed (*e*).

Fig. 107.—*Pleurophorus quadricostatus.*

Fig. 108.— *Cardinia sub-angulata.*

Isocardia.—Like *I. transversa*, De Koninck, but narrower. A cast from East River, Pictou. Collected by Mr D. Fraser.

Cardinia nana, De Koninck, coll. J. W. D., Onslow, in an impure, black, flaggy limestone.—The specimens are larger than the Belgian, but otherwise similar.

Cardinia sub-angulata, n. sp. (Fig. 108), coll. J. W. D., Pugwash.—Form oval, with an obscure ridge from the beak to the lower part of the posterior end. Surface covered with irregular lamellar lines of growth.

Cardinia Antigonesensis, n. sp., coll. J. W. D., Antigonish.—Regularly oval, but somewhat narrower posteriorly; beak a little in front of the middle. Breadth rather less than half the length. Surface marked with delicate growth lines, but smooth.

Arca punctifer, n. sp., coll. Hartt, Windsor.—Shell broad oval in form, truncate posteriorly, the tumid beaks and middle portion descending abruptly behind to the straight hinge-line. Surface with regular flattened concentric ridges, crossed, especially near the posterior margin, by oblique radiating lines, each composed of a thin ridge bearing a row of minute papillæ. Bed (*a*). The specimen is only a fragment, but must have been nearly an inch broad and two inches long when entire.

Cardiomorpha Vindobonensis, Hartt (Fig. 109).—This species is known only by casts, one of which is faithfully represented in the figure.

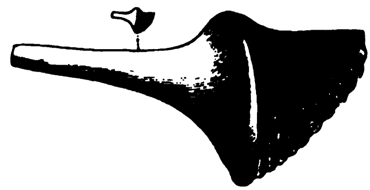
Cardiomorpha Archiacana, De Koninck, occurs with the above in the Windsor limestones.

Conocardium Acadianum, Hartt (Fig. 110), coll. Hartt, Windsor.—Triangular, with a very prominent central ridge. Prolonged posteriorly into a very long wing or siphonal tube. Anterior slope marked

with radiating ribs, about twelve in number, and becoming wider and flatter toward the margin. Length about three lines.

Fig. 109.—*Cardiomorpha Vindobonensis* (*cast*).

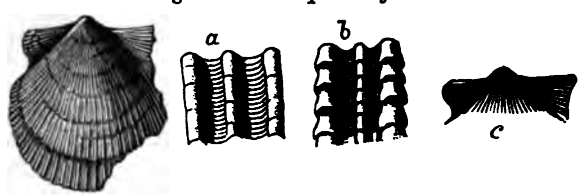
Fig. 110.—*Conocardium Acadianum; nat. size and magnified.*



Conocardium.—A fragment of a cast of a much larger species, with very distinctly marked scaly ribs, occurs in Mr Hartt's collection from Stewiacke.

Aviculopecten Lyelli, n. sp., coll. J. W. D. and C. F. Hartt (Fig. 111), Windsor, Shubenacadie, etc.—Shell orbicular, as wide as long,

Fig. 111.—*Aviculopecten Lyelli.*



(*a*) and (*b*) Varieties of sculpture; (*c*) hinge-line.

narrowed behind, hinge-line equal to three-fourths the longitudinal diameter. Left valve slightly convex, greatest convexity being just behind the middle, sloping thence gradually to the border, where it is almost plane; umbo well marked, and quite strongly incurved. Ears flattened, the posterior not separated from the umbo, but sloping gently therefrom. Anterior separated from the umbo by a narrow, steep, smooth slope. Anterior ear rounded, and with a wide shallow notch under it; posterior pointed, and with its lateral margin concave. Surface of valves ornamented by about sixty rounded, well marked, radiating plaits, separated by deep furrows as wide as the plaits. The plaits increase both in height and breadth in going from the umbo to the margin. They increase near the front and sides by implantation. Those on the side of the valve are slightly curved; on the umbo they can scarcely be distinguished. The plaits are ornamented by numerous sharp squamous processes, which appear to be arranged in concentric rows. These rows are separated by a space equal to that between

the plaits. The plaits in the internal cast appear nodose. The ribs are visible in the cast of the interior, but less distinctly. In some specimens which have the surface well preserved, the tubercles in the ribs become elegant scaly processes, and in others the spaces between the ribs have regular microscopic concentric lines between the ribs. In others there are occasional coarse concentric ridges. Though at first disposed to regard some of these varieties as distinct, the comparison of a great number of specimens induces me to regard them as varieties of the same species. It is allied to *A. fallax*, M'Coy, and *A. occidentalis*, Shumard.

Aviculopecten reticulatus, n. sp., coll. J. W. D. (Fig. 112), Gay's River.—In form and size similar to the last, but the left valve much flattened, and the surface marked with numerous sub-equal ribs, crossed by strong concentric striæ, giving a reticulated appearance.

Fig. 112.—*Aviculopecten reticulatus*; *Sculpture magnified.*

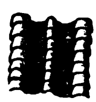
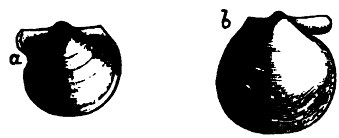


Fig. 113.—*Aviculopecten simplex.*



(*a*) Sinistral, and (*b*) dextral valve.

Aviculopecten simplex, n. sp. (Fig. 113), coll. J. W. D., Shubenacadie Windsor, etc.—Shell semi-orbicular, equivalve, very convex, the thickness being equal to half the transverse diameter, greatest just behind the middle, sloping thence with a gradual curve to the front, hinge-line less than longitudinal diameter. Ears well marked, anterior ones abruptly flattened, that of the right valve being flatter than the other, and separated from the umbo by an oblique groove. Anterior ear of left valve with a shallow rounded notch; that of the right valve much deeper. The groove separating the ear from the umbo is concave, narrow and shallow at first, but becomes wider and deeper until it runs into the notch. The right valve has a narrow, concave, triangular area. Umbones approximate, much inflated. That of left valve touches and passes slightly beyond the hinge-line. That of the right is elevated above the hinge-line by the hinge-area. Surface of valves generally smooth, ornamented by a few more or less prominent concentric lines of growth.

This species approaches to *A. pusillus* of the Permian, but differs in being more tumid, more nearly circular, and having longer ears. A single valve found in the Upper Coal formation limestone approaches still more nearly to *A. pusillus*. It may represent another species,

or a variety of the preceding. Its nearest relative in the Carboniferous of Europe is, I think, *P. gibbosus* of M'Coy.

Aviculopecten Acadicus, Hartt (Fig. 114).—Left valve minute, 5-32ds of an inch in width, circular, arched, umbones not distinctly seen, posterior flattened moderately, not distinctly separated from the umbo. Surface of valve, exclusive of the ears, which are not exposed, ornamented by ten primary, narrow, prominent, raised radiating lines, separated by a space equal to twice the width of one of the lines. In these spaces secondary lines arise, not attaining the dimensions of the primaries, so that the surface is covered with alternately large and small lines; there are also a series of delicate concentric lines, which gives to the surface a reticulated appearance.

A single specimen of this pretty little shell occurs in Mr Hartt's collection from bed (*a*) at Windsor. It seems quite distinct from the others.

Aviculopecten cora, n. sp. (Fig. 115), coll. J. W. D., Shubenacadie. —Similar in general form to *A. Lyelli*, but more regularly tumid, longer, with smaller ears, and the surface regularly marked with very fine radiating striæ, resembling those of *Productus cora*.

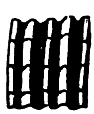


Fig. 114.—*Aviculopecten Acadicus; sculpture magnified.*

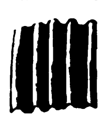


Fig. 115.—*Aviculopecten cora; sculpture magnified.*

Fig. 116.—*Aviculopecten Debertianus.*

Aviculopecten.—Fragments of large specimens from the Shubenacadie; have broad nodose ribs, resembling *Pecten plicatus*.

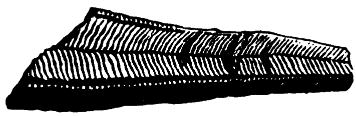
Aviculopecten Debertianus (Fig. 116), n. sp., collected by J. W. D., Lower Limestone, De Bert River.—Shell rather flat, broader than long, small; breadth less than half an inch. Anterior ear narrow, convex, separated by a deep notch from the margin. Posterior ear very small. Surface in perfect specimens marked with concentric furrows and obscure radiating lines. This species resembles *P. pusillus* more nearly in general form than any of the preceding, but in the ears is nearer to *P. depilis*, M'Coy.

Pteropoda.

Conularia planicostata, n. sp. (Fig. 117), coll. J. W. D., Irish Cove, Cape Breton, Windsor, and Shubenacadie.—Form very elongate, pyramidal. Cross section square, but by pressure becoming rhombic; surface marked by thin raised ribs, in perfect specimens with very

delicate oblique striæ on their edges. The ribs vary much in their distance in different parts of the same specimen, and in different

Fig. 117.—*Conularia planicostata.*



specimens (from five in a line to ten in a line). They form an angle of about 120° in the middle line of each face—breadth of full-grown specimens about half an inch; length, two inches or more. There is no indication whatever that this shell had any internal partitions, though it occurs both flattened, as at Big Plaister Rock, and retaining its original form, as at Irish Cove and Windsor. Mr Hartt has proposed the name "Nova Scotica" for a more elongated form, with finer and more numerous ribs; but on comparing numerous specimens, I am inclined to regard it as a variety. The shell of *Conularia* is usually regarded as that of a Pteropod, which seems the most probable view. If the shell of a Cephalopod, it must have been of the nature of a straight *Argonauta*. It is curious to observe in the flattened specimens that the shell always gives way at the edges, without breaking, as if there was a suture or weak line there. The shell was exceedingly thin, especially at the smaller extremity, where it seems to terminate in an obtuse rounded form. The aperture in the best specimens rises at the sides in angles corresponding to those of the plications.

Gasteropoda.

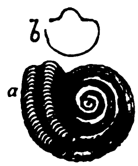
Euomphalus, a small species with narrow whorls, resembling *E. quadratus*, M'Coy, but slightly rounded above and marked with lines of growth, appears in fragments in Mr Hartt's collections from Windsor, and seems to be the same with still more imperfect specimens in my own collection from the galena-bearing limestone of Gay's River. A small species, similar to *E. lævis*, also occurs in Mr Poole's collections from Windsor.

Euomphalus exortivus (Fig. 118), n. sp., coll. J. W. D., East River, Pictou.—About half an inch in diameter, with about five narrow whorls coarsely marked with lines of growth, and with a strong rib along the middle of the whorls above. Collected by Mr D. Fraser.

Bellerophon.—I have a specimen collected by Professor How at

Kennetcook, which indicates a fine shell of this genus; but it is only a cast of the interior, and gives no good specific characters.

Fig. 118.—*Euomphalus exortivus.*



(*a*) Shell partly preserved. (*b*) Cross section.

Turbo.—To this genus I refer, in the meantime, two pretty little species contained in my own collections from Pugwash, and those of Mr Hartt from Windsor. One is a little shell with four whorls, and about twenty folds in the suture. It occurs at Pugwash and Windsor. The other is similar in size and form, with seven or eight revolving lines. It is found at Windsor.

Dentalium.—In my collection from Economy and Pugwash are casts which may represent two species of this genus,—one circular in outline, the other oval and slightly curved; but both are too imperfect for description.

Naticopsis Howi, Hartt (Fig. 119), col. J. W. D. and C. F. Hartt, Windsor, Gay's River, De Bert River, etc.—Allied to *N. plicistria*, Phillips, but different in markings, having merely delicate growth lines on the whorls, and always of small size.

Fig. 119.—*Naticopsis Howi.*

Fig. 120.—*Naticopsis dispassa* (*cast*).

Fig. 121.—*Platyschisma dubia.*

Naticopsis dispassa, n. sp. (Fig. 120), coll. J. W. D., Pugwash, Windsor.—A small species of the type of *N. ampliata*, Phil., and marked in the same way with delicate transverse lines of growth, but flatter in general form, and less depressed in the spine.

Platyschisma dubia, n. sp. (Fig. 121), coll. H. Poole, Windsor.—I refer to this genus with doubt the shell represented in the figure. It seems to be very rare, as I have only met with one example.

Loxonema acutula, n. sp. (Fig. 122), coll. Hartt, Windsor.—An extremely slender species, scarcely two lines long, and with fifteen or more whorls, marked with traces of four or five revolving lines. It corresponds to *L. polygyra*, M'Coy, and *L. acicula*, Phillips, but is more slender and delicate than either.

Murchisonia gypsea, n. sp. (Fig. 123), coll. H. Poole, Windsor.—Like *M. nana*, De Koninck, but larger, and with only two revolving ridges on the whorls.

Fig. 122.—*Loxonema acutula, magnified.*

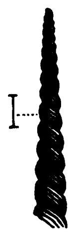


Fig 123—*Murchisonia gypsea* (*cast*)

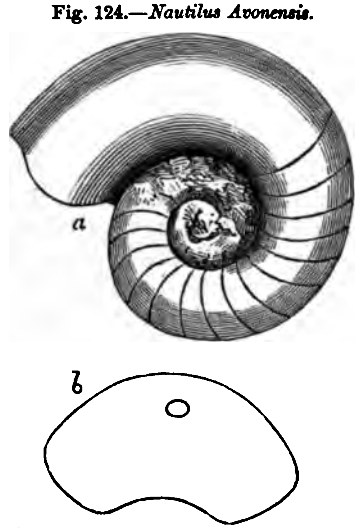
Murchisonia tricingulata, n. sp., coll. J. W. D., Windsor, Pugwash.—Resembles *M. angulata*, Phil., but has a keel above as well as below the central band on the whorls.

Pleurotomaria dispersa, n. sp., coll. H. Poole, and Hartt, Windsor.—There are several small species of this genus. One, which is very abundant in bed (*b*), Hartt, at Windsor, is that above named. It has four flat whorls, giving it an almost regular conical form, with delicate striæ across the whorls.

Pleurotomaria ignobilis, n. sp., coll. Hartt, Windsor—Almost exactly of the form and markings of *P. nobilis*, De Koninck, with three revolving carinæ; but without the delicate sculpture between the carinæ.

Cephalopoda.

Fig. 124.—*Nautilus Avonensis.*

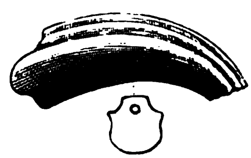


(*a*) Shell of small size. (*b*) Cross section.

Nautilus Avonensis, n. sp. (Fig. 124), coll. J. W. D., Windsor, Minudie.—A large species, the outer chamber sometimes two inches or more in diameter. Whorls much flattened dorso-ventrally, slightly angulated at inner edge. Siphuncle dorsal, septa convex, about one-eighth of an inch apart. Belongs to genus *Cryptoceras*, D'Orbigny. Abundant at Windsor, and named after the Avon River, on the banks of which it occurs.

Gyroceras Harttii, n. sp. (Fig. 125). A fragment of a small angulated species, resembling *N. sulcatus*, Sowerby, coll. J. W. D., Windsor.—It has the whorls somewhat quadrate, with two broad flutings at the sides, and two narrower flutings at the edges of the flat dorsal surface. The inner surface is regularly rounded, and the siphuncle is dorsal.

Fig. 125.— *Gyroceras Harttii.*



Orthoceras laterale, Phil., collected by Professor How at Kennetcook.—Resembles this species, as figured by De Koninck, too closely to permit me to distinguish it.

Orthoceras dolatum, n. sp. (Fig. 126), coll. J. W. D., Windsor.—Like *O. pygmaeum*, De Koninck, in external form. Siphuncle marginal, slightly beaded; shell flattened at one side. Septa one-half the larger diameter distant from each other.

Fig. 126.—*Orthoceras dolatum.*

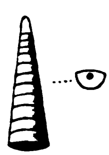


Fig. 127.—*Orthoceras Vindobonense.*

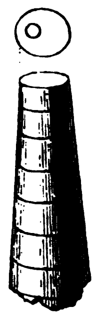
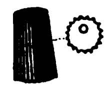


Fig. 128.—*Orthoceras laqueatum.*



Orthoceras Vindobonense, n. sp. (Fig. 127), coll. J. W. D., Windsor.—Section nearly round. Siphuncle about one-third the diameter

from the side. Septa distant from each other rather less than one half the diameter. Resembles *O. laterale*, but is smaller, more cylindrical, and with the septa more distant in proportion.

Orthoceras laqueatum, Hartt (Fig. 128), coll. Hartt, Windsor.—Round, with submarginal siphuncle, and about twenty-six regular smooth flutings. Resembles *A. Gesneri*, De Koninck, but differs in being round, destitute of sculpture on the flutings, and with septa more distant from each other—about one-third of the diameter of the shell.

Orthoceras perstrictum, n. sp. (Fig. 129), coll. Hartt, Windsor.—A fragment of a small species with very regular transverse microscopic striæ, much finer than those of *O. conquestum*, Koninck, the siphuncle sub-marginal, and the septa deeply concave, and distant from each other nearly the diameter of the shell.

Fig. 129.—*Orthoceras perstrictum.*

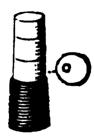


Fig. 130.—*Serpulites Hortonensis.*

Articulata.

Spirorbis angulatus, n. sp., coll. J. W. D., Windsor, on shells of Brachiopods.—Differs from *Spirorbis carbonarius* in the angular form of the whorls, which rise to an edge above, and in being smooth, with fewer whorls more rapidly increasing in size. It is very like the modern *S. Nautiloides* of our coasts.

Serpulites Hortonensis, n. sp. (Fig. 130), coll. Professor How, Halfway River.—Smooth or obscurely annulated, half a line in diameter. Nearly straight toward the aperture, coiled in a discoid manner at the smaller end. Some specimens have a grooved appearance longitudinally, but I believe this to be due to crushing. This shell perhaps belongs rather to the Lower Coal formation shales than to the properly marine beds.

Serpulites annulatus, n. sp. (Fig. 131), coll. H. Poole and C. F. Hartt, Windsor.—Cylindrical, about a line in diameter, coarsely marked with rings of growth and coiled in a loose irregular spiral.

Serpulites inelegans, n. sp., coll. Hartt, Windsor, bed (*b*).—Cylindric, tapering, marked with faint transverse striæ, slightly waving in form; greatest diameter, 1-6th inch; length, 1½ inch.

Beyrichia Jonesii, n. sp. (Fig. 132), coll. Hartt, Windsor.—Length about 1-10th inch, breadth 2-3ds of length. Very tumid; surface

divided by two deep furrows, proceeding toward the ventral margin form a circular pit nearly in the centre, and diverging at an angle of about 60°. Margin very narrow; outline nearly semi-circular. It is nearly allied to *B. Kloedeni* of the Devonian.

Phillipsia Howi, Billings (Fig. 133), "Canadian Naturalist," vol. viii. p. 209.—This species was described by Mr Billings from specimens found by Prof. How of Windsor, at Kennetcook, Hants County. It is closely allied to *P. meramecensis*, Shumard, and *P. insignis*, Winchell, from the Lower Carboniferous of the United States, but differs in the greater number of rings in the axis of the pygidium

Fig. 131.—*Serpulites annulatus.*

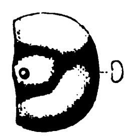


Fig. 132.—*Beyrichia Jonesii; nat. size and magnified.*

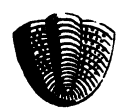


Fig. 133.—*Phillipsia Howi.*

or tail-piece, the only portion known. These Phillipsias of the Carboniferous are very interesting as the last representatives of the great family of Trilobites, so abundant in the older Palæozoic rocks.

Phillipsia Vindobonensis, Hartt.—Pygidium semi-elliptical, very convex; one or two segments appear to be wanting from the anterior margin; but the width of the pygidium in that part must have been greater than its length. Ten or eleven articulations are visible on the side lobes and twelve on the axis, which is very prominent and moderately tapering. The axial rings are depressed, convex, becoming smaller, more crowded, and more indistinct toward the apex. Ribs on side lobes depressed, convex, decreasing in length, breadth, and distinctness from before backward, while at the same time they become more and more inclined backward. The six anterior ribs preserved show a distinctly marked groove, originating on the posterior margin at about one-third the length of the rib from the axis, and running obliquely, increasing in depth to the end of the rib. Smooth border none, or extremely narrow at anterior angles, but becoming 3-5ths the width of the axis *near* the posterior part of pygidium, which is not visible in the only specimen I have examined.

Crustacean.—In Mr Hartt's collection there is a single fragment which would seem to indicate a Crustacean different from the Trilobites, and probably of higher type. It occurred in bed (*e*), and must await the discovery of additional remains.

Actinoceras.—The species represented at the end of this chapter (Fig. 133 *a*), and which has only recently come under my notice, was collected by Mr D. Fraser on the East River of Pictou. I have named it *A. inops.*

Anthracosia.—The only species of this genus known to me in Nova Scotia was omitted inadvertently from its proper place in this chapter. It was found by Mr J. Barnes at Baddeck, Cape Breton, in a brownish shale of the Lower Carboniferous, and is figured at the end of the chapter under the name *A. Bradorica* (Fig. 133 *b*).

It is a curious fact that, except a few teeth of fishes, no remains of vertebrate animals have yet been found in the marine limestones which have afforded the above species of invertebrates. This is the more remarkable since remains of fishes are so abundant in the Lower Carboniferous shales, and also in the Coal formation.

Though I have noticed in the above list about 87 species of animals, I think it probable that many more remain to be discovered; indeed there are in the collections now in my hands imperfect specimens which indicate the existence of several others. These limestones must continue for some time to afford a rich field to industrious collectors; and it is much to be desired that those who may engage in this work would place their collections where they may be studied and described, as there is no doubt that many fine specimens from these beds are buried in the cabinets of amateurs, and have been practically lost to science.

Fig. 133 *a.*—*Actinoceras inops, n. sp.*

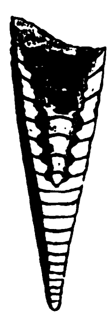
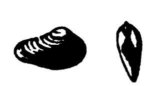


Fig. 133 *b.*—*Anthracosia Bradorica, n. sp.*



CHAPTER XVII.

THE CARBONIFEROUS PERIOD—*Continued.*

CARBONIFEROUS DISTRICTS OF PICTOU, ANTIGONISH, AND GUYSBOROUGH; ISOLATED PATCHES AT MARGARET'S BAY AND CHESTER BASIN.

Carboniferous District of Pictou.

In noticing this and the following districts, I shall avail myself of the details into which we have entered, to enable me to condense my descriptions, and to dwell only on those features that may be peculiar, or very dissimilar from those already described. In entering the Pictou coal district from Colchester, we pass over disturbed and somewhat altered Lower Carboniferous sandstones and conglomerates, with intrusive and metamorphic rocks on either side, forming outlying masses of the Eastern Cobequids. The first characteristic and distinctly marked beds that we find are the limestones on the upper part of the West River. At the Salt Springs these limestones, with their accompanying sandstones, are seen in a vertical position, and with their fissures filled with micaceous iron-ore,—a very decided proof of igneous action. There appears to be in this part of the Pictou district a considerable area of altered Carboniferous rocks, showing that in this vicinity active volcanic agencies have subsisted after the deposition of the Lower Carboniferous series. A little farther down the West River, at M'Kay's Lime Rock, we find the limestone unaltered, and containing *Crinoids*, *Terebratulæ*, *Fenestella*, *Corals*, and other fossils, similar to those of the limestones of Hants and Colchester, and more especially to the *lower* limestones already mentioned. Having thus reached a known member of the Carboniferous series, we may take a general glance over the district, with the aid of the map, and mark the distribution of its principal rock formations.

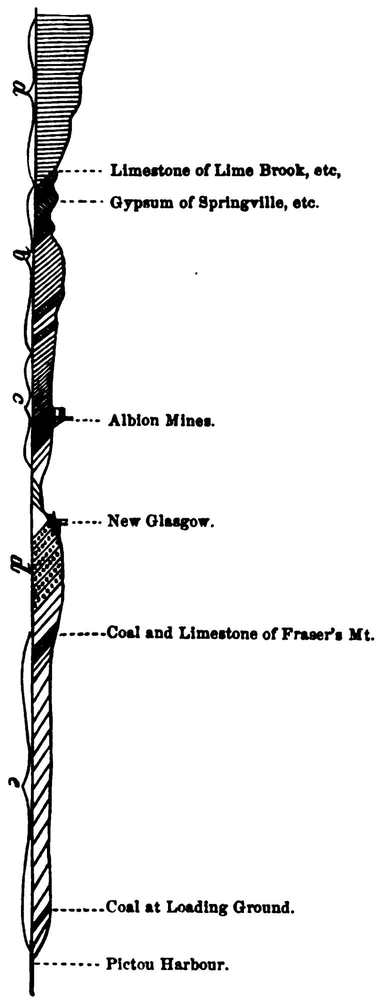
From the West River we can trace the limestones and other members of the Lower Carboniferous series to the East River, along the valley of which they enter, in the form of a narrow bay, into the metamorphic district to the southward. Beyond the promontory of these latter rocks bounding this inlet on its eastern side, the Lower Carboniferous

rocks continue to skirt the older hills as far as the coast of the Gulf of St Lawrence at M'Cara's Brook, near Arisaig, where they rest unconformably on slates belonging to an older formation. The lowest Carboniferous rocks seen here are conglomerates interstratified with beds of amygdaloidal trap, which have flowed over their surfaces as lava currents, just as the trap of the Bay of Fundy has flowed over the red sandstone. Several of these ancient lava streams alternate with beds of conglomerate; and while their lower parts have by their heat slightly altered the underlying bed, their upper parts, cooled and acted on by the waves, have contributed fragments to the overlying conglomerate. Over these conglomerates is a great series of reddish and gray sandstones and shales, similar to those we have observed elsewhere. They contain no gypsum, but there is a thick limestone with a number of the fossil shells already noticed in similar beds of this age. Along the whole southern edge of the Pictou district, therefore, we observe the Lower Carboniferous series, distinguished by its characteristic fossils, and containing beds of limestone and gypsum, though the latter, as well as the associated marly beds, is less important than in Hants County. To the northward of these older members of the system, we find in some localities, and especially on the East River, a large development of the productive or Middle Coal measures; and the remaining part of the district, stretching along the coast of Northumberland Strait, and connected with the eastern part of Cumberland, presents precisely the same characters which we have observed in the last-mentioned district, of which it is strictly a continuation.

The most remarkable feature in the Pictou district is the enormous thickness of Coal measures on the East River, forming the Albion Mines Coal-field; and these deserve a detailed notice, not only from their economical importance, but their geological interest, as presenting a vastly greater development of coal seams and their accompaniments than we have observed elsewhere. I shall therefore describe the general arrangement of the rocks on the East River with the aid of the sections (Figs. 134 and 136).

The oldest Carboniferous bed that I have observed on the East River is a limestone resting directly on the edges of a hard metamorphic slate, which must have formed the sea-bottom on which the former rock was deposited. Angular fragments of the slate are included in the lower part of the limestone. This limestone, which appears at Lime Brook on the east branch of the East River, contains in its upper part fossil corals of the genus *Lithostrotion*, already described as *L. Pictoense*. On this limestone rest marls with gypsum veins, and at least one large bed of gypsum and anhydrite, the outcrop of which

appears distinctly at Forbes Lake and Creelman's Farm on the East Branch, and less conspicuously at Springville. Above these gypseous rocks, which, being soft, have been eroded into a valley, is another



(a) Silurian slates. (b) Lower Carboniferous series. (c) Coal measures. (d) Great conglomerate. (e) Upper Coal formation.

Fig. 134.
General Section of the Carboniferous Rocks of the East River of Pictou.
(See also Fig. 136).

limestone rich in fossil shells, including many of those already noticed and some others. Succeeding this in ascending order is a great series of hard brownish sandstones and shales, like those of Eagle's Nest on the Shubenacadie, and probably corresponding to the lower members

of Sir W. Logan's Joggins section. These occupy the East Branch and Main River for some distance. They contain a few fossil plants, in one instance impregnated with carbonate and sulphuret of copper; and at least two beds of limestone, not rich in fossils, but affording the characteristic species *Terebratula sacculus*, *Streptorhyncus crenistria*, and *Productus semireticulatus*. One of these limestones, seen near the forks of the river, is remarkable for showing, when slices are examined under the microscope, that it is made up of small fragments of shells with entire specimens of very minute species.* The rocks in this part of the section are much fractured; but a comparison with the continuation of the same beds in M'Lellan's Brook, shows that the order is ascending, and that the Coal measures rest on the rocks last described.

The Coal measures of the Albion Mines consist of the same materials, and contain many of the same fossil remains with those of the Joggins; but they differ in the arrangement of these materials and fossils. Instead of a great number of thin beds of coal and bituminous shale, we have here a few beds of enormous thickness, as if the coal-forming processes, so often interrupted at the Joggins, had here been allowed to go on for very long periods without interference. It is almost a necessary consequence of this that erect plants are not found in the Albion measures, and that well-preserved vegetable fossils are comparatively rare, while vast quantities of vegetable matter have been accumulated in the state of coal. The sections at the Albion Mines are not perfect. They show, however, five or six seams of coal, and an immense thickness, perhaps 800 feet, of black shales with *Cypris* and remains of ferns and other leaves. There are also underclays and ironstones abounding in *Stigmaria*.

In attempting to give a general idea of the structure of this coal-field, I shall first notice the order and succession of the beds, then their distribution, and next some remarkable and exceptional features which they present, as compared with the districts previously noticed.

The section of the beds, in descending order, as made up from a comparison of the results of borings and excavations by the different coal companies, is as follows:—

	Ft.	in.
Gray freestone or sandstone	15	3
Black shale and clay, with layers of dark argillaceous sandstone and ironstone †	419	9
Forward,	435	0

* See Table in last chapter.

† These beds are given from the observations of Mr Hudson in the Forster Pit, Albion Mines.

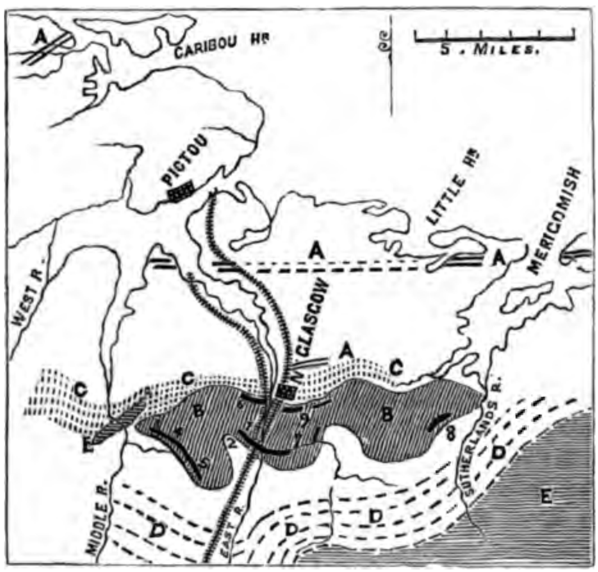
	Ft.	in.
Brought forward,	435	0
Main Coal seam (greatest thickness)	39	11
Sandstone, shale, and ironstone	157	7
Deep Coal seam	24	9
Shales, sandstone, and ironstone, with several thin coals, viz. the Third seam, "Purves seam, and Fleming seam," in all about twelve feet thick . .	280	0
M'Gregor Coal seam	11	0
Shale, with many beds of sandstone and layers of ironstone and underclays	240	0
Coal and earthy bitumen, "Frazer coal and Stellar coal"	4	0
	1192	3

The above is to be regarded as a mere approximation, and the measurements are taken in a line perpendicular to the surface, the beds being inclined at an angle of about 20°. In this section it will be observed that the total thickness of beds is less than in the Middle Coal measures of the Joggins section, but that the quantity of coal is vastly greater. In other words, the deposit of vegetable matter has been greater and more continuous, and that of earthy matter less.

When the first edition of this work was published, the extension of the Pictou Coal seams was known only in the Albion mining area near the East River, where the dip is to the north-east and the strike north-west. Subsequent explorations by Mr Poole, recorded in a paper published in the "Canadian Naturalist," showed that about a mile and a half westward of the river the beds are bent and faulted, and turn suddenly to the southward. It was afterwards ascertained by Mr J. Campbell, and by the agents of the "Acadia" and "Nova Scotia" Companies, that the line of outcrop takes an extensive curve of more than a mile to the southward, forming the area of the "Intercolonial" Company, and then, sweeping again to the northward, resumes a north-westerly course, passing toward the Middle River. Here it would seem to turn round the end of a synclinal, or to be cut off by a fault in its extension with northerly dip, and it is next seen to return on a curved line, skirting a ridge of older rock, probably of Devonian age, and a conglomerate connected with this, toward New Glasgow; near which, on the Haliburton or "Montreal and Pictou" area, the beds appear with high dips to the southward. The East River Coal area between that river and the Middle River would thus appear to constitute an irregular trough with a deep bay to the southward, and

possibly a gap on the north, as represented on the sketch-map (Fig. 135), which I must, however, remark is merely an attempt to reduce to order complexities not as yet fully intelligible. The relations of this trough to the rocks to the northward we shall leave until we have attempted to trace the synclinal in its extension to the East.

Fig. 135.—*Sketch-map of Pictou Coal District.*



A, Upper Coal formation.
B, Middle Coal formation.
C, New Glasgow conglomerate.
D, Lower Carboniferous.
E, Devonian and Silurian.

Coal Areas.—(1) General Mining Association, or Albion Mines; (2 and 4) Acadia; (3) Nova Scotia or French's; (5) Intercolonial or Bear Creek; (6) Montreal and Pictou or Haliburton's; (7) German Company, and others; (8) Sutherland's River; (9) New Glasgow or Kirby's.

At the date of the publication of the first edition of "Acadian Geology," little was known of the extension of the Albion Coal measures to the eastward of the East River. I could at that time only indicate the occurrence of Coal measures with a dip showing a considerable fold or bend of the measures in M'Lellan's Brook, and the probable extension of the productive Coal measures in the direction of Merigomish. Subsequent observations by Mr Poole threw additional light on the bend of the measures, and more recently several discoveries of coal have been made, and I have seen, through the kindness of Mr Moore of Montreal, plans prepared by Mr Barnes of Halifax which appear to me approximately to establish the true distribution of the beds.

It would appear that immediately to the east of the East River, a synclinal fold, apparently with some disturbance in its axis, occurs. This throws the beds round into the north-westerly dips seen in M'Lellan's Brook. Beyond this there is an anticlinal, succeeded by a second synclinal, on the east side of which, in the vicinity of Sutherland's River, the coal beds reappear with north-westerly and northerly dips. The most eastern exposure on this tortuous line of outcrop is a bed stated to be ten feet in thickness, seen near Sutherland's River, about two miles from its mouth.

No doubt the coal beds extend still farther to the eastward, along or under Merigomish Harbour, and they will also be found in all the belt of country between Sutherland's River and the East River.

The line above indicated refers to the northerly dipping outcrop continuous with that of the Albion Mines; but fronting this there is, on the east side of the East River, as indicated in the general section in the first edition of this work, and reproduced without alteration in Fig. 134, a narrow line of outcrop, in which some at least of the beds reappear with southerly dips along the line of the fracture which skirts the outcrop of the great New Glasgow conglomerate. This exposure is continuous with that already noticed immediately opposite New Glasgow, and includes the beds long known in the vicinity of that place on the east side of the river, with others recently traced farther to the south and east.

Eastward of New Glasgow, according to observations made by Mr Kirby on his coal areas, the line of strike curves somewhat to the northward, forming a broad indentation parallel to the projection on the opposite side of the trough, and then, returning toward the south, passes toward the shores of Merigomish Harbour, where its extension has not yet been observed. The beds of the Upper Coal formation which are seen at Little Harbour, appear in Merigomish Island apparently without any synclinal arrangement between them and the Lower Carboniferous rocks of the adjacent mainland. There is, however, a considerable space concealed by Merigomish Harbour, and by the beach between Merigomish Island and the mainland, and it is to be observed that the Upper Coal formation beds on the island dip to the north, while those on the nearest part of the mainland dip to the N. W., and seem to belong to the lower part of the Coal formation. This indicates either intervening curves or dislocations, or that the upper series is unconformable to the lower.

In the above general notice mention has been made of a great bed of conglomerate occurring immediately to the northward of the East River Coal trough, and which, as it appears very conspicuously at

New Glasgow Bridge, we may designate as the "New Glasgow Conglomerate." At New Glasgow this conglomerate dips at a high angle to the north, but at the Middle River and several other places it is found dipping to the south, and the relations of the Coal measures to it on the northern side of the Albion Mines trough, in the vicinity of New Glasgow, would seem to render it certain that the conglomerate underlies the productive Coal measures, and crops out from beneath them on an anticlinal line. This would give it the geological position of the Millstone-grit series, but no such massive conglomerate is known in that series elsewhere, though there are conglomerate beds of minor dimensions. Again, the beds on the north side of the conglomerate, and evidently overlying it, are not those of the productive Coal measures as developed at the Albion Mines, but Coal measures of minor importance, believed to represent the Upper Coal formation; and these supposed Upper Coal formation beds exhibit very regular northerly dips, as if they had not participated in the foldings and fractures of the beds of the Middle Coal formation. Lastly, toward the Middle River there appears, rising from beneath the conglomerate, a series of hard and altered grits and coarse shales, with obscure remains of fossil plants, which were pointed out to me in the summer of 1866 by Mr John Campbell, and which I believe to be an island of older rock which must have penetrated the Carboniferous beds, and protruded above them at the time of their deposition, representing on a very small scale the attitude of the Cobequid Hills with reference to the Coal formation of Colchester and Cumberland.

These statements being premised, as well as the further fact that the opinions of geologists in regard to this conglomerate have oscillated between the extreme views that it is a bed overlying the Middle Coal measures, and forming the base of the Newer Coal formation, and, on the other hand, that it is the Lower Carboniferous conglomerate thrown up along the line of an anticlinal,—I proceed to quote from the first edition of this work and the supplement thereto, published in 1860, the reasons which I then assigned for believing that it is a contemporary beach of shingle, limiting the area of deposition of the thick coal seams of the Albion Mines area, and giving rise to their exceptional character. This view was first advocated in my paper on the structure of the Albion Coal Measures in the Journal of the London Geological Society, 1853; and the reasons for it are thus given in the first edition of this work:—

"1. The outcrop of the conglomerate extends from a point opposite the promontory of metamorphic rock east of the East River to the high lands of Mount Dalhousie, in the eastern extremity of the Cobe-

quid range of hills, crossing the mouth of an indentation in the metamorphic district, which in the older part of the Carboniferous period must have been a bay or arm of the sea, exposed to an open expanse of water lying to the northward. 2. The conglomerate cannot be traced to the margin of the metamorphic country, except at its extremities; so that in all probability it never extended over the low Carboniferous district included within its line of outcrop. This is the more remarkable, inasmuch as the conglomerate has evidently resisted denudation better than any of the associated beds. 3. The conglomerate is full of false stratification and wedge-shaped beds of reddish sandstone in the manner of ordinary gravel-ridges, and it even presents the appearance of passing into sandstone toward the dip, as if the coarse conglomerate were limited to the vicinity of the outcrop. 4. In the sandstone overlying the Albion measures, as well as in portions of the Coal formation manifestly overlying the great conglomerate, there are small seams of coal corresponding in their characters with those of the Joggins and Sydney, where no similar conglomerate occurs. 5. The supposition that the Albion coal was formed in a depressed space, separated by a shingle-bar from the more exposed flats without, accounts for the great thickness of the deposits of coal and carbonaceous shale, the comparative absence of sandstones, and the peculiar texture and qualities of the coal, as well as the association with it of remains of fish and *Cypris;* since modern analogies show that such an enclosed space might be alternately a swamp and lagoon without any marked change in the nature of the mechanical deposits. 6. Movements of depression causing the rupture of the barrier, or enabling the sea to overflow it, and perhaps also admitting currents of oceanic water through the valleys of the metamorphic district to the southward, would sufficiently account for the overlying sandstones, as well as for the denudation of the Coal measures supposed to have preceded the accumulation of these sandstones.* 7. The dislocation extending along the outcrop of the conglomerate is easily explained by the supposition that, in later elevatory movements, this hard and strong bed determined the direction of fracture of the deposits.

"To these reasons I may add, that if in the Carboniferous as in the modern period, westerly winds prevailed in this latitude, it would be very natural that a beach should be thrown out from the eastern end of the Cobequid range across the bay to the eastward, in which the Albion Coal measures are situated."

In the supplementary chapter (1860), after referring to some

* These sandstones overlie the Coal measures near the Albion Mines, but with dip to the N.

additional observations made by Henry Poole, Esq., I concluded as follows :—

"The facts above stated in no respect shake the conclusion that the New Glasgow conglomerate is contemporary with the Albion Coal measures, and the remains of a great accumulation of shingle separating these from the more open space without. On the contrary, they tend to confirm it; and none of the fossils obtained by Mr Poole indicate any recurrence of Lower Carboniferous rocks in the anticlinal which throws up the conglomerate in association with beds of the Middle Coal measures. A very remarkable fact stated by Mr Poole is perhaps a proof of the contemporaneous disturbances and changes of level connected with the original formation of this conglomerate. He says,—'There are numerous small faults running across the measures in the Fraser Mine, which are uniformly downthrows to the west; and I may here mention that I observed, some years ago, in the Deep seam, several faults from four to ten feet each, which could not be found in the main coal workings above (the distance between the two seams is 157½ feet), which shows that the disturbances must have taken place previous to the formation of the Main Coal Seam.'"

I now hold that the additional fact above stated, of the occurrence of a ridge of older rock penetrating the conglomerate between the East and Middle Rivers, gives further confirmation of this theory of the relation of the conglomerate. This ridge of older rocks must have been surrounded with a deposit of gravel in the Millstone-grit period, and so often thereafter as the area was submerged, either on one side or the other; and with its associated gravel-ridge must have formed just such a dam or barrier as is required to account for the very exceptional character of the enormous coal beds of the area included within it. It results that *the New Glasgow conglomerate is not that of the Lower Carboniferous, which underlies the marine limestones, but is to be regarded as an anomalous and peculiar modification of the Millstone-grit*, succeeded in ascending order on the south side by the great Coal measures of the Albion Mines, and on the north by a depauperated representative of these beds, graduating upward into the Upper or Newer Coal measures.

I may further remark that the relation of these latter beds to the conglomerate and the hard rocks below it, is similar to that which I believe obtains on a larger scale along some parts of the northern and eastern slope of the Cobequids. If the view above given is correct, it would follow that the Coal measures on their return dip to the south near New Glasgow should present some marked points of difference, as compared with those of the Albion Mines, and that there may be places where their outcrop has been so far spared by denudation as to

roximate to the original margin of the thick beds in this direction. ꞉h a place I should expect to find in the bend of the outcrop to westward of Mr Haliburton's mine opposite New Glasgow.

have endeavoured to represent to the eye the above theoretical ws in the following ideal sections:—

Fig. 136, *a*.—*Ideal section representing the supposed mode of growth of the great Pictou Coal beds.*

(*a*) Devonian island or reef; (*b*) gravel; (*c*) peaty swamp; (*d*) flats outside reef often inundated; (*e*) Lower Carboniferous beds.

Fig. 136, *b*.—*Ideal section representing the present arrangement of the Coal formation of East River, Pictou.*

(*a*) Devonian ridge; (*b*) conglomerate; (*c*) great Coal measures; (*d*) minor Coal measures; (*e*) Lower Carboniferous; (*f*) Silurian.

If these views are correct, we have a right to expect that the tract Coal formation country to the northward of the great conglomerate, 1 extending from it to the eastern extremity of the Cumberland trict, should present characters similar to those of that district. cordingly the section on the tideway of the East River, and the responding sections on the Middle River, and on the coast toward

Merigomish, show a series of Coal formation rocks not very dissimilar from some parts of the Joggins section. Their dips are to the northward, and in their lower part there is a bed of concretionary and laminated limestone, the only fossil in which appears to be the little *Spirorbis* already so frequently mentioned. Almost immediately above this limestone is a small bed of impure coal, probably two feet thick. These beds are accompanied by some black shales, and succeeding them, in ascending order, is a series of sandstones and shales abounding in leaves of ferns, calamites, etc. The highest beds seen on the south side of Pictou Harbour and at Merigomish are thick bedded gray sandstones, which afford grindstone and building stone, and abound in petrified coniferous wood; and with these are associated some shales and underclays, with thin seams of coal, one of which in Merigomish Island is eleven inches thick. In the continuation of the same series, coal has been found at the loading ground at South Pictou, and near the mouth of the Middle River.

Northward and westward of Pictou Harbour, which occupies a synclinal depression, is a series of rocks, nearly resembling those just described, and generally dipping to the south-east at angles of 15° to 25°. In Roger's Hill, six miles westward of Pictou, are thick beds of coarse conglomerate, considerably disturbed, associated with greenstone and hard claystone, and showing in one part a vein of crystalline sulphate of barytes. This conglomerate I believe to be geologically identical with that of New Glasgow. It is succeeded by a great series of deposits, chiefly consisting of reddish sandstones and shales; but including several thick beds of gray sandstone, affording quarries of valuable grindstone and freestone, and accompanied by gray shales, conglomerates, thin beds of coarse limestone, and thin beds of coal. As there are no very good natural sections in this part of the country, it would be difficult to ascertain the aggregate thickness of these deposits; it must, however, be great, since they occupy, with general south-east dips, the whole country from the hills last named to the entrance of Pictou Harbour. The principal fossils found near Pictou are *Calamites*, *Lepidodendron*, *Endogenites*, coniferous wood, ferns, *Sternbergia*,* and carbonized fragments of wood impregnated with iron pyrites and with sulphuret and carbonate of copper. In this series also, and near the town of Pictou, is a bed of sandstone containing erect calamites, evidently rooted *in situ*, and described in a paper by the writer in the Proceedings of the Geological Society for 1849. The appearances at this place are so similar to those observed at the Joggins, and they need not be noticed here; but these and the occurrence of *Stigmaria in situ* in some of the shales and sandstones

* Transversely wrinkled stems, believed to be casts of the pith of plants.

of the same neighbourhood, serve to indicate the analogy that obtains between the coal-rocks of Cumberland and this part of Pictou. Some of the shales near the town of Pictou are loaded with ferns and *Cordaites;* and shells of a *Naiadites* (*N. arenacea*) also occur, though rarely. Small seams of coal are believed to occur in this neighbourhood, but their outcrops cannot at present be seen.

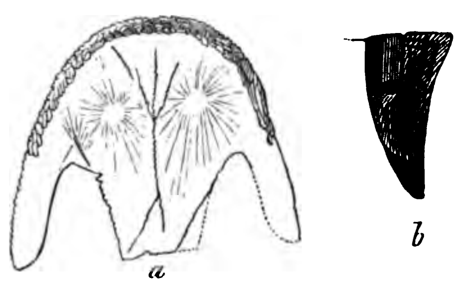
The coast section, westward of the entrance of Pictou Harbour, is for some distance very imperfect. Much red sandstone, however, appears; and a bed of limestone from two to three feet thick, and a small bed of coal, have been discovered. Some gray sandstones also appear; in one of which there are numerous fragments of carbonized wood, containing sulphuret aud carbonate of copper. This deposit, and others of a similar nature found in this series at various places, have given rise to hopes that valuable deposits of copper may be found in this part of the Coal formation. These ores of copper are always associated with remains of fossil plants, and they have no doubt been produced by the deoxidizing effects of this vegetable matter on water impregnated with sulphate of copper, and probably rising in the form of springs from some of the older subjacent rocks.

The rocks in the coast section west of Pictou Harbour dip to the south-eastward as far as the mouth of Carribou River, beyond which the same beds are repeated, but better exposed, and dipping to the north. One of the cupriferous beds above referred to, a coarse gray sandstone, appears in Carribou River, and was at one time worked for the copper it contains, but is now abandoned. At the mouth of the river are gray sandstones, red sandstones, and red and gray shales, and associated with these is a bed of coal five inches in thickness, with the usual underclay with *Stigmaria* rootlets. Beyond this place, as far as the second brook beyond Toney River, there is a great series of beds having precisely the aspect of the Upper Coal formation of Cumberland, and containing one thin bed of non-fossiliferous limestone, and a great thickness of reddish shales, some of them finely ripple-marked and worm-tracked, and with leaves of ferns. The beds then become horizontal, and are repeated with southerly dips (S.S.E.), at first at a small angle, but toward the extremity of Cape John the dip increases, and the rocks at length become vertical. The lowest beds seen at the extremity of the cape are gray coarse sandstones, with *Calamites* and carbonized trunks of trees. Associated with these are reddish sandstones and shales, and in front of the cape, but under water, is the outcrop of a small bed of gypsum. The northerly dipping beds in the above section extend to the westward across River John, and are continuous with those described (*vide* Cumberland District) as occurring on the French river of Tatamagouche. The

southerly dipping beds towards Cape John probably extend under Tatamagouche Bay, and are continuous with the rocks on the south side of Cape Malagash.

A coal district so singular in its structure, and probably also in the mode of formation of its beds, as that of the Albion Mines, might be anticipated to afford interesting and peculiar fossils. Unfortunately, however, these beds are not exposed in good natural sections, and the operations of the miner are a very imperfect substitute for these. One bed, however, included in the Albion main coal has afforded some interesting facts. It is a seam of coaly ironstone varying in thickness from four inches to a foot, and in some portions of the mine is extracted with the coal and thrown aside as rubbish, so that large quantities of it can be examined at the surface. It contains abundance of *Spirorbis*, attached to much-decayed plants. Scales and teeth of large fishes are also found in it, as well as fragments of the bony spines with which they were armed.* Some of the latter are half an inch in diameter. A still more interesting fossil was found by the writer in this bed in 1850. It is the upper part of a skull, seven inches in breadth and five inches in length, and armed with strong conical teeth, somewhat curved, and finely striated longitudinally (Fig. 137). This fossil was sent to London, and examined by Professor

Fig. 137.—*Outline of Skull of Baphetes Planiceps reduced; and Tooth, natural size.*



(*a*) Anterior part of skull, viewed from beneath.
(*b*) One of the largest teeth, natural size.

Owen, by whom it was described and figured in the Proceedings of the Geological Society (1853) under the name of *Baphetes Planiceps*, alluding to its supposed amphibious habits, and the flatness of its skull. This creature was probably a large frog-like reptile, which preyed on the fishes whose remains are found with it in the "holing stone," as the bed is called by the miners. It will be more fully described in the next chapter. This band, with its peculiar fossils, shows that, at Pictou as at the Joggins, the coal-forming area was

* See page 210 *ante*.

occasionally submerged under brackish water, perhaps by the partial rupture of the great conglomerate bank to which we have already referred.

Useful Minerals of the Pictou District.

Coal is the most important of these; and Pictou was long the principal producer of this valuable mineral in British America, having only recently been outstripped by the Coal-field of Cape Breton. Upwards of 237,000 tons were raised in 1866. The greater part of the Pictou coal is shipped to the United States, and is used in iron-foundries and gas-works, and for the production of steam. The principal mines are those worked by the General Mining Association and the Acadia Company, though several other collieries are being put into working condition. I may shortly notice the principal coal areas in succession.

(1.) *General Mining Association* (Fig. 135—1).

The coal hitherto exported by this Company has been obtained principally from the "main seam" (see p. 319), and chiefly from its upper twelve feet, though in recent years the lower part of this seam, and also the "deep seam," have been worked. The pits originally worked were on the low ground immediately west of the East River, where an engine-pit was sunk to the depth of about 400 feet. In the progress of these works, however, it was found that the coal deteriorated very much in quality in its extension to the eastward; and this circumstance, in connexion with a serious "crush" in the mine, determined the proprietors to make new openings to the westward, named the Dalhousie pits, as well as others toward the dip. These are the present working pits. In the Dalhousie pits the whole thickness of the main seam and also the deep seam are worked. In 1866, the Foster pit, 450 feet deep, was sunk near the Dalhousie pits, and a new shaft is being made in advance of the old eastern workings, and will be of considerably greater depth. An interesting historical sketch of these mines, with a notice of their present state, is given by Mr Rutherford, Inspector of Mines, in his Report for 1866, from which I quote the following:—

"The extraordinary thickness of the beds of coal in these collieries has given them a well-deserved celebrity; the number as well as the size of the seams in this coal-field being perhaps unparalleled. Having been in operation many years, a large extent of coal has been mined. Only two seams have, however, been sunk to and worked, viz., the main seam and the deep seam,—the latter lying 25 fathoms below the

former, and being the next in the series in descending order. They dip to the north-east at an angle of 20°, or about 1 in 2¾. The thickness of the main seam is so well known that it is unnecessary to give a section of it. Its average thickness may be stated to be 38 feet. Several shafts have been sunk to the seam, the workings in connexion with which have received a peculiar classification, which had its origin in the following circumstances:—A large tract of workings to the rise of the shafts, which are distant from the crop 250 yards, extending 800 yards to the west and 200 yards to the east of them, and covering an area of about 40 acres, forms the earliest worked portion of the seam. In nearly the whole of this district about 12 feet only of the upper part of the seam has been worked, the lower portion being considered inferior in quality. These workings are locally known as the "burnt mines," and are so designated in consequence of a fire that occurred some years ago in the stables, and was only extinguished by closing the shafts to prevent the admission of the air into the mines. Further to the dip other shafts have been sunk, and they, with some situated 960 yards to the west, and known as the Dalhousie pits, are the present working shafts. From the former of these the workings were considerably extended both east and west; they are in the upper part of the seam only, and their extent is about 90 acres. In some workings to the dip of these an accident occurred in May 1861, which was attended with still more disastrous results than the preceding one, it being found necessary to fill the mine with water in order to extinguish the fire. An attempt was made to get into these workings in 1862, but their condition was such that they were abandoned, and this district, from this circumstance, has received the name of 'Crushed Mines,'—a designation sufficiently indicative of the state of the workings on re-opening the mine.

"The main seam is at present worked on the east side of the 'Crushed Mines,' and in the Dalhousie pits on the west side. In the latter, the seam has been worked the entire thickness, the lower portion being much improved in quality. The extent of workings in this district is now upwards of 100 acres.

"The difficulty of working a seam of such a thickness and with such a declination has unfortunately been exemplified during the last two years in this district of the mine. Whilst the *modus operandi* remained the same, a change appears to have been made in the scale of pillarage to meet the requirements of so largely an increased height of seam, which, however, proved inadequate, and a large extent of workings has been and still is under the effect of a crush in consequence.

"The system of working pursued from the commencement of the

colliery has been continued ever since, with some modifications in the size of the pillars. The bords are driven 18 feet wide, and the pillars are made from 8 to 18 yards thick, with holdings at irregular intervals. No regular pillar working has been attempted in this seam.

"The 'deep seam' is worked at the Dalhousie pits only. Its average thickness is 15′ 6″. It is worked the entire height of the seam, and on the same principle as the main seam; the bords and pillars being of a similar size. The workings are altogether on the west side of the pits; and the main level in that direction has been driven 1600 yards. It is about 250 yards from the crop. The workings extend over an area of 60 acres, the whole of which is standing in pillars, with the exception of a few near the face, a partial working of which has recently been begun.

"An extension of the works at these mines is in progress. During the year a new shaft has been sunk to the main seam near the face of the west workings. This shaft is 450 feet deep to the top of the seam, and is intended to be used for drawing coal. A steam-engine for hoisting has been erected, and a railway between the pit and the main line in part constructed. Another shaft has also been begun to the dip of the 'Crushed Mines' pits, and is now upwards of 300 feet deep. An additional shaft for ventilation has been put down near the crop of the deep seam, and a slope is being driven in the main seam, to be connected with the pit above referred to. The working powers of this already extensive colliery will, on the completion of these works, be much increased."

The following detailed section, taken from a continuous specimen of the main seam, extracted for the New York Industrial Exhibition by Mr Poole, late manager of the mine, will enable the reader to understand the available amount of good coal which the main seam contains, as well as the structure of the bed. As this section has, since the publication of my first edition, been copied without acknowledgment, and in terms leading to the inference that it was drawn up in New York, I may state that it was prepared by myself from a careful inspection of the specimen, to which I was kindly invited by Mr Poole, while it lay on the ground after having been extracted from the mine.

	Ft.	In.
1. Roof shale: vegetable fragments and attached *Spirorbis* (in specimen)	0	3
2. *Coal*, with shaly bands	0	6½
3. *Coal*, laminated; layers of mineral charcoal and bright coal; band of ironstone balls in bottom	2	0
Carry forward,	2	9½

		Ft.	In.
	Brought forward,	2	9½
Worked in old mine.	4. *Coal*, fine, cubical, and laminated; much mineral charcoal	3	2
Worked in old mine.	5. Carbonaceous shale and ironstone, with layer of coarse coal ("holing stone"); remains of large fishes and coprolites. This bed varies much in thickness	0	4½
Worked in old mine.	6. *Coal*, laminated and cubical, coarser towards bottom	9	3
	7. Ironstone and carbonaceous shale, with coaly layers and trunks of *Lepidodendron*, *Ulodendron*, *Sigillaria*, *Stigmaria*, etc., all prostrate	0	8
	8. *Coal*, laminated as in No. 6, a line of ironstone balls in bottom	1	2
Worked in 2d floor.	9. *Coal*, laminated and cubical, a few small ironstone balls; many vascular bundles of ferns in this and underlying coal	6	7
Worked in 2d floor.	10. Ironstone and pyrites	0	3
Worked in 2d floor.	11. *Coal*, laminated and cubical, as above	10	3
	12. *Coal*, coarse, layers of bituminous shale and pyrites	1	0
	13. *Coal*, laminated, with a fossil trunk in pyrites	2	1
	14. *Coal*, laminated and cubical, with layers of shale, passing downward into black slicken-sided underclay with coaly bands	2	3
	15. Underclay (to bottom of specimen)	0	10
	Thickness perpendicular to horizon	40	8
	Vertical thickness	38	6

From this seam at least 24 feet in vertical thickness of good coal can be extracted. A cubic foot of Pictou coal weighs about 82 lbs., rather less than 28 feet being equal to a ton of coal; hence a square mile of this seam would yield in round numbers 23,000,000 tons of coal—an enormous quantity as compared with the present annual produce, but less than two-thirds of the annual consumption of Great Britain. The other seams in the Albion measures may be safely estimated at half the value of the main seam.

The Albion coal has a laminated texture, and much mineral charcoal on its surfaces, and is a highly bituminous caking coal. Its specific gravity, according to the trials of Professor W. R. Johnston,* is 1·318 to 1·325. The result of twelve trials made by the writer of samples from different parts of the mine was, that the specific gravity varies

* Report to the United States Government on American Coals.

from 1·288, which is that of the best coal extracted, to 1·447, which is that of the coarsest coal that has been worked. The mean specific gravity of six samples, taken from the top, middle, and bottom of the seam, in the central part of the mine, was 1·325, or exactly the same with one of Professor Johnston's results. According to Professor Johnston's trials, 1 pound of this coal is capable of converting 7·45 to 7·48 pounds of water into steam, or from the temperature of 212°, 8·41 to 8·48 pounds. This gives it a high place among bituminous coals as a steam-producer. The worst defect of Pictou coal is, that it contains a considerable quantity of light bulky ashes; and this causes it to be much less esteemed for domestic use than on other grounds it deserves. It is very free from sulphur, burns long, with a great production of heat, and remains alight when the fire becomes low much longer than most other coals.

The following assays show the composition of the coal from the upper floor in different parts of the mine, and illustrate its gradual deterioration at either extremity of the workings.

		S.E. side: Old workings (about 1 mile E. of Dalhousie Pits).	N.W. side: Old workings.	W. side: Dalhousie Pits.
Fall Coal.	Moisture	1·750	1·550	Thinned out
	Volatile combustible	25·875	27·988	
	Fixed carbon	61·950	60·837	
	Ashes	10·425	9·625	
		100·000	100·000	
Top Bench.	Moisture	1·500	1·500	2·2
	Volatile combustible	24·800	28·613	22·7
	Fixed carbon	51·428	61·087	62·0
	Ashes	22·272	8·800	13·1
		100·000	100·000	100·0
Bottom Bench.	Moisture	2·250	1·800	2·5
	Volatile combustible	22·375	27·075	22·7
	Fixed carbon	52·475	59·950	58·8
	Ashes	22·900	11·175	16·0
		100·000	100·000	100·0

It will be observed that in all parts of the mine the lower coal is inferior to that of the middle of the seam, and still more so to that of the upper part above the "holing stone," or the "fall coal," as it is termed by the miners. It will also be observed that all the coals in the first column are inferior to those in the second, and that those in

the third are also inferior, while in this part of the mine the upper three feet of fall coal have disappeared, or been reduced to an insignificant thickness, by thinning out or being replaced by shaly matter.

The following table gives the composition of all the varieties of coal in the whole thickness of the seam, as ascertained by an elaborate series of assays made by the writer in 1854:—

Assays of Samples of Albion Coal, taken at distances of one foot in thickness, in the main seam.

No.		Volatile matter by rapid coking.	Volatile matter by slow coking.	Carbon fixed.	Ashes.
1.	Coal ...	26·0	19·9	63·8	16·3
2.	Do. ...	27·8	24·1	63·8	12·1
3.	Do. ...	27·4	25·7	60·0	14·3
4.	Do. ...	27·2	25·0	65·5	9·5
5.	Do. ...	25·8	25·1	64·8	10·1
6.	Do. ...	25·2	24·9	62·5	12·6
7.	Do. ...	27·4	22·0	68·5	9·5
8.	Do. ...	26·8	22·9	66·7	10·4
9.	Do. ...	27·0	23·9	61·3	14·8
10.	Carbonaceous shale	16·4	15·9	26·3	58·8
11.	Coal ...	28·8	25·8	59·7	14·5
12.	Do. ...	27·2	25·4	62·5	12·1
13.	Do. ...	27·6	24·7	65·5	9·8
14.	Do. ...	26·6	23.9	61·0	15·1
15.	Do. ...	26·8	23·1	65·1	11·8
16.	Do. ...	28·8	24·9	62·3	12·8
17.	Do. ...	30·4	26·0	65·0	9·0
18.	Do. ...	26·0	26·1	63·0	10·9
19.	Do. ...	26·0	25·0	66·3	8·7
20.	Do. ...	26·8	22·7	63·6	13·7
21.	Coarse coal	25·8	23·3	58·3	18·4
22.	Do. ...	27·2	22·5	60.3	17·2
23.	Coal ...	29·4	23·6	64·3	12·1
24.	Coarse coal	25·8	22·4	57·6	20·0
25.	Do. ...	25·8	23·1	60·2	16·7
26.	Do. ...	27·8	21·9	54·8	23·3
27.	Coal ...	27·0	24·3	65·5	10·2
28.	Do. ...	25·6	22·4	65·0	12·6
29.	Do. ...	25·8	22·7	62·7	14·6
30.	Do. ...	27·2	23·1	67·4	9·5
31.	Do. ...	32·6	22·4	66·5	11·1
32.	Coarse coal	22·2	21·5	50·4	28·1

These coals being taken from the western part of the workings, do not show the fall coal of the old pits, this part of the seam having there, as already explained, thinned out. All these coals afford a fine vesicular coke, and their ashes are light gray and powdery, with the exception of those of the coals marked "coarse," which are heavy and shaly.

The *Deep Seam*, situated at the vertical depth of 150 feet below the main seam, and consequently cropping out to the surface about 150 yards to the south-west of the outcrop of the latter, contains about twelve feet of good coal, divided by intervening layers of shaly and impure coal into three bands. The best coal of this seam is superior to that of the main seam, but owing to the division above mentioned, it cannot be worked so economically as the main seam, and is therefore likely to be left until the latter is exhausted, at least in its more accessible portions. The comparative purity of some portions of this seam, however, would entitle them to demand a higher price in the market than the ordinary produce of the Pictou mines. Its best portions contain only from 5·3 to 11 per cent. of ashes, and afford much illuminating gas, and a fine vesicular coke, similar to that of the main seam coal. The ashes of some of the deep seam layers are of a reddish colour, whereas those of the coal from the main seam are invariably white or light-gray. There can be no doubt that nothing but its association with a bed of so much greater magnitude prevents this seam from being more extensively worked.

The following sectional view of the Deep Seam as it occurs at the Dalhousie pits, is taken from a series of samples furnished to me by Mr Poole in 1854:—

1. Gray argillaceous shale—roof.
2. Tender laminated coal, much mineral charcoal.
3. Laminated compact coal, less mineral charcoal.
4. " "
5. Carbonaceous ironstone, crusts of *Cyprids*.
6. Laminated compact coal, much mineral charcoal.
7. Laminated coarse coal.
8. Laminated compact coal.
9. Laminated coarse coal.
10. Laminated compact tender coal.
11. Laminated compact coal.
12. Laminated compact coarse coal.
13. Laminated compact hard coal.
14. " " thick layer of mineral charcoal.

15. Laminated compact coal.
16. „ „ much mineral charcoal.
17. „ „ „
18. Shaly coal, impressions of plants.

The results of assays of these several samples are given in the following table:—

Assays of Samples of Coal taken at distances of one foot in the Deep Seam.

No.		Volatile matter by rapid coking.	Volatile matter by slow coking.	Carbon fixed.	Ashes.
2.	Good coal ...	24·8	21·0	67·6	11·4
3.		25·2	25·2	67·3	7·5
4.		28·4	23·9	70·8	5·3
5.	Ironstone and coal	26·8	27·5	18·5	54·0
6.	Coarse coal ...	23·2	20·5	59·1	20·4
7.		23·6	20·4	48·0	31·6
8.	Good coal ...	26·2	22·4	70·3	7·3
9.	Coarse coal ...	25·2	22·1	49·3	28·6
10.	Good coal ...	24·8	20·4	68·9	10·7
11.		24·8	22·3	64·3	13·4
12.	Coarse coal ...	23·4	20·5	51·2	28·3
13.		23·0	20·1	55·3	24·6
14.	Good coal ...	27·4	23·9	68·1	8·0
15.		29·0	22·9	71·5	5·6
16.		26·8	21·9	69·6	8·5
17.		24·6	19·9	63·8	16·3
18.	Shale and coal	17·6	21·1	23·0	55·9

The following summary of these two beds and the intervening measures, from the observations of Mr Poole in sinking the first engine pit at the Dalhousie Mine, gives at the same time an idea of the gigantic development of workable coal at this place.

	Ft.	in.	Ft.	in.
Surface clay			8	2
Shale and bands of ironstone alternate .			64	10
Main Seam—				
Coarse coal . . .	0	2		
Good coal . . .	5	0		
Ironstone . . .	0	6		
Good coal . . .	14	4		
Ironstone . . .	0	4		
Coarse coal . . .	7	7		
Ironstone . . .	0	4		
Carry forward,	28	3	73	0

	Ft.	in.	Ft.	in.
Brought forward,	28	3	73	0
Coarse coal . . .	3	1		
Ironstone . . .	0	4		
Coarse coal . . .	2	11		
Ironstone . . .	0	5		
Coarse coal . . .	4	11		
	39	11	39	11
Shale and bands of ironstone alternate .			157	7
Deep Seam—				
Bad coal	0	2		
Good coal . . .	3	10		
Ironstone . . .	1	2½		
Coal	3	7¾		
Slaty coal . . .	0	9¼		
Good coal . . .	4	2		
Coarse coal . . .	1	0½		
Good coal, "worked by Carr"	3	8		
Inferior coal . . .	6	3		
			24	9
Total			295	3

As Pictou coal is now largely used in the manufacture of illuminating gas, the following comparative trials of the volume of gas which it affords, made by the writer in the spring of 1854, may be interesting. They were made on a small scale, by means of an iron retort and graduated glass vessels; but their accuracy was afterwards confirmed by trials of some of the coals on the large scale in the Pictou Gas-work.

	Cubic feet per Ton.
Coal from upper nine feet of the main seam, from the Dalhousie pits, ...	3902
Coal from middle of main seam, the portion now mined in the lower floor	5080
Coal from upper three feet of best coal of deep seam, . .	6668
Coal from lower three feet of best coal of deep seam, . .	8504

The average yield of the first of these samples in the Pictou Gas-work is about 4000 cubic feet. As some of the other coals now worked are even more productive of gas, it may be anticipated that

the reputation of Pictou coal in the gas-works will increase. I may mention here that the value of Pictou coal for this purpose, as well as for family and steam uses, depends in part on the good quality of its coke, and in part on its comparative freedom from sulphur. These excellent qualities, in connexion with its great heating power, more than compensate for its large percentage of ash as compared with some other coals.

(2.) *Acadia Coal Company* (Fig. 135—2, 4).

The principal area worked by this Company lies immediately to the north of that of the General Mining Association, or toward the rise of the beds. Its chief value therefore depends on the lower seams of coal, and more especially those known as the M'Gregor and oil coals.* The M'Gregor seam is that from which the greater part of the coal of this Company is extracted. It is worked by "slopes" or galleries extending downward from the outcrop, and up which the coal is drawn on rails.

The M'Gregor seam is stated by Mr Hoyt,† the general agent of the Company, to be 12 feet in thickness, as follows:—

	Ft.	in.
Coal (first bench)	2	6
Shaly band	0	6
Coal (second bench)	3	0
Coal (coarse)	4	0
Shale	0	7
Coal (good)	1	5
	12	0

At present only the two upper benches, or six feet in all, are worked, and the coal obtained from these is of very good quality, containing on the average, according to an analysis obtained from Mr J. D. B. Fraser of Pictou, the former proprietor of the mine, only about 8 per cent. of ashes. The thickness of the coal is stated to increase in working to the westward, and to diminish to the eastward; and it is somewhat remarkable that its quality improves with its thickness. According to the report above cited, the quality and reputation of this coal will depend much on the care taken to separate the material of the "shaly band" from the good coal, as the presence of this material greatly increases the amount of ash, and deteriorates the coke, though it does not seem materially to affect the yield of gas, which amounts to the large return of 9500 feet from a ton of 2240 lbs.

* For position of these coals, see section *ante*. † Report, 1866.

About five feet above the M'Gregor Seam there is a smaller seam, three feet three inches thick, and of good quality, which may perhaps in future be worked in connexion with the other. The other seams between the M'Gregor and Deep Seams, known as the "Purves Seam" and "Third Seam," are said to be each four feet in thickness, but are not worked.

Under the M'Gregor bed, as shown on the general section above, lies a very curious bed, known as the "stellar" or "oil" coal. It is five feet in thickness, having, according to Mr Hoyt, the following section:—

	Ft.	In.
Bituminous coal	1	4
Stellar oil coal	1	10
Bituminous shale	1	10
	5	0

The material known as stellar coal is, as I have maintained in previous publications, of the nature of an earthy bitumen; and geologically is to be regarded as an underclay or fossil soil, extremely rich in bituminous matter, derived from decayed and comminuted vegetable substances. It is, in short, a fossil swamp-muck or mud, which, as I have elsewhere pointed out,* is the character of the earthy bitumens and highly bituminous shales of the Coal formation generally. Its value depends on the high percentage of illuminating gas and of mineral oil which it yields on distillation; and it is likely, on this account, to form an important portion of the produce of this coal area. According to the results of different trials, it is stated to yield from 50 to 126 gallons of oil per ton, the larger amount being apparently the yield of the pure "stellar coal," so named from its scintillatory appearance in burning. According to an analysis by Professor How of Windsor, this gives,—

Volatile matter	66·33
Fixed carbon	25·23
Ash	8·21
Moisture	·23
	100·00

The sample to which the above analysis refers gave of crude oil 120 gallons per ton.

The immense amount of petroleum obtained from wells in Canada

* Paper on Conditions of Accumulation of Coal, "Journ. of Geol. Soc."

and the United States has for the present diminished the demand for the earthy bitumens; but it is certain that they must again come largely into use, as the wells diminish in their yield and additional uses are found for the mineral oils.

In addition to the area south of that of the General Mining Association, the Acadia Company possess a property to the westward, in which the continuation of the main and other seams occurs in magnificent proportions, and with the same characters as in the Campbell or Bear Creek area of the Intercolonial Company, next to be noticed.

(3.) *Intercolonial and Nova Scotia Companies* (Fig. 135—5, 4).

In addition to the collieries above described, there are others organized, and which have made more or less progress toward extensive mining operations. The Bear Creek area, the property of the Intercolonial Company, and first developed by Mr John Campbell, is probably the most important, and has recently been examined and reported on very favourably by Mr Charles Robb and Mr Barnes. It includes the continuation of the main and other seams beyond the great flexure or downthrow at the western extremity of the area of the General Mining Association, already referred to. In a pit sunk on the main seam by Mr Campbell, I found the section of that bed to be as follows:—

Roof, black shale.	Ft.	in.
Tender good coal	0	11
Shaly coal	0	1
Good coal	5	3
Shaly parting	0	4
Good coal	4	0
Pyritous coal	0	2
Good coal	7	0
Coarse coal	2	0
Total thickness .	19	9

The dip is N. 75° E. at an angle of 20°, and the actual thickness eighteen feet of coal, of which sixteen feet are of excellent quality. It appears from this section, and from trials which I have made of the coal, that the main seam in its extension to the westward, while it diminishes in thickness, improves in quality. Still farther west, on the property of the "Acadia" and "Nova Scotia" Companies, where slopes have been opened in this seam, the section is substantially the same, except that in the latter the shale or clay-parting thickens to eleven inches.

On the Bear Creek area the deep seam also has been recognised in its proper place, and has a thickness at right angles to the measures of eleven feet.* Other beds, supposed to be the equivalents of the Purves and M'Gregor Seams, the latter six feet in thickness, have also been found. These discoveries enormously increase the ascertained extent and value of the Pictou Coal-field, as compared with that at the time of the publication of my first edition; and when taken in connexion with the previous observations made by Mr Poole, leave no room whatever for the doubts which I find expressed by some practical men as to the precise equivalency of the beds last mentioned with those so long known at the Albion Mines.

(4.) *Montreal and Pictou Company* (Fig. 135—6).

The only colliery as yet opened on the northern side of the Coal trough, on this side of the East River, is that of the Montreal and Pictou Company, immediately opposite to New Glasgow. Here the Coal measures dip, according to Dr Honeyman,† S. 20° E. at an angle of 65°. A shaft has been sunk to a depth of 180 feet; and, according to a Report by Mr Rutherford, published by the Company, has exposed the following section of Coal measures. The measurements are at right angles to the horizon, so that the thickness given does not represent the actual vertical thickness:—

	Ft.	in.
Drift clay	15	0
Shale	13	0
Freestone	0	10
Shale	10	0
Coal	10	6
Fire-clay	10	6
Hard sandstone	3	6
Fire-clay and Ironstone	3	0
Dark shale	3	0
Coal	9	0
Shale and coal	2	0
Fire-clay	9	0
Ironstone band	0	5
Coal	2	6
Fire-clay	10	0
Coal	15	6
Fire-clay	16	0
	133	9

* Robb's Report.

† Letter to the Author.

If, as is probable, these beds represent the Albion Mines Coal measures, or a part of them, it is evident that in crossing the trough they have materially changed in the character and thickness of the beds of coal. This was to have been anticipated from the views previously stated, as the shaft which afforded the above section is only about 600 yards from the conglomerate, and consequently the locality cannot be very far from the original margin of the trough in this direction. In the circumstances, the discovery that the coal preserves its value thus near to the conglomerate, and is so accessible, is very gratifying, and greatly enhances our estimation of the value of this coal-field as a whole. I must add, however, that it is scarcely fair to say, in the words of a recently published public Report, that this discovery has given to the coal-field "a conformation which appears to have been entirely unsuspected." The synclinal form of the measures was indicated in the former edition of this work, and is a necessary consequence of the view as to the character of the great conglomerate advocated therein. It was more fully stated in the paper by Mr Poole and myself in the "Canadian Naturalist" for 1860, and in my supplementary chapter in "Acadian Geology;" and the outcrops of coal near New Glasgow, on this side of the trough, had long been known. The conformation or structure of the area had thus been established by geological investigation before the coal was discovered opposite New Glasgow; but this in no respect detracts from the credit due to the gentlemen whose energy and enterprise have developed the coal-beds in that locality. It is all the more creditable to them that their operations were not undertaken on chance, but on a consideration of probabilities established by facts previously ascertained. The facilities for shipping the coal in the area above referred to are very great, and there can be little doubt that the outcrops discovered will be traced farther to the westward, and perhaps afford scope for additional collieries in this direction. The high angle at which the beds lie will require different management in the details of mining from that which has been usual in the Picton Coal-field, and it is not improbable that this high angle will be connected with numerous fractures and abrupt flexures of the strata.

(5.) *Coal Areas on the East Side of the East River* (Fig. 135—7, 8, 9).

Openings have been made by the "German" Company on the continuation of the main seam eastward of the East River. The result is stated to have been, that the quality of the coal was found to be unsatisfactory,* and operations were consequently abandoned. This would appear to show that the inferiority of the main seam coal

* Rutherford's Report, 1866.

observed in the eastern working of the General Mining Association extends beyond their property on the east side of the river. I have attributed this to the effects on the process of coal formation produced by the spur of older metamorphic rock which extends forward into this part of the coal area from the southward, and in this case the deterioration may apply to a considerable area near the southern edge of the trough, but the coal may be expected to improve in following it toward the dip. I regret that I have not any details as to the precise aspect and character of the coal as exposed by the German Company, as this might have enabled more precise conclusions as to its cause and extent to be arrived at.* The appearance of workable coal farther eastward toward Sutherland's River has been already referred to, and on the opposite side of the trough, eastward of New Glasgow, two beds of coal, stated at four feet each in thickness, have been found. Much additional exploration is required in this part of the area, to ascertain the arrangement of the strata, and also the peculiar character and distribution of the beds of coal, which may be expected to differ materially from those on the west side of the river.

(6.) *Other Parts of the Pictou Coal-field.*

The small seams of coal seen at Merigomish Island, Little Harbour, Fraser's Mountain, South Pictou, and Carribou, appear to belong to a second and upper series of coal seams, as compared with those of the Albion Mines, or more properly, perhaps, two distinct groups of coals.† They have not been ascertained to be of workable value, and, as already stated, may be considered as the representatives of the Upper Coal formation or the upper part of the Middle Coal formation, as developed at the South Joggins. The facts already stated show that the productive Coal measures on the East River belong to a special and limited coal area, while the beds northward of the New Glasgow conglomerate belong to a larger area, continuous to the north with that of Cumberland. For this reason, we should not be disposed to expect in this wider area, surrounding Pictou Harbour, a repetition of the great beds of the Albion Mines, but there is no reason to suppose that the coal actually present is limited to the thin beds just mentioned. On the contrary, the analogy of the Cumberland Coal-field would lead us to expect that under these beds, and cropping out northward and

* A hand specimen from this mine, for which I am indebted to Mr Barnes, in its highly laminated and shaly character, corresponds with what might be expected on the views above stated.

† The coal-beds of Fraser's Mountain, Little Harbour, and Merigomish Island, are very probably members of one group of coal-seams, and those of the loading ground and other places near Pictou Harbour of a second and higher group.

westward of Pictou Harbour, there should be other and perhaps more valuable beds. At present, however, little is known of the detailed structure of this part of the Pictou Coal-field, and the distance from navigable water of those portions of it in which coal is likely to be found, prevents any expensive explorations from being made. I anticipate that the careful tracing, for practical purposes, of the northern edge of the East River Coal-beds, along and around the New Glasgow conglomerate, will, in a few years, give data which may be employed to work out the true relations and practical value of such beds as may occur in the area now under consideration.

Minerals other than Coal.

Clay Ironstone occurs in the Pictou Coal measures, apparently of good quality, and in sufficient abundance to be extracted profitably, if in a country in which smelting-furnaces are in operation. At present, however, no attention is paid to it. From the abundance of boulders of *Brown Hematite* scattered over the surface of the Lower Carboniferous rocks on the East River, I have inferred that veins of that rich ore of iron exist in these rocks, in the same manner as at the Shubenacadie. The outcrop of these veins had not been observed at the time of the publication of my first edition, but I am informed by Dr Honeyman that veins of this mineral have recently been discovered *in situ*, and that there is reason to believe that they penetrate the Silurian rocks. The presence of these ores, in connexion with a large bed of peroxide of iron in the older slates to be hereafter described, leaves little doubt that were other circumstances favourable, iron-works might be established on the East River without any deficiency in the raw material. The following analysis of the ore is by Professor How of Windsor:—

Peroxide of iron, with traces of phosphoric acid	84·54
Alumina and phosphoric acid	0·19
Sesquioxide of manganese	0·76
Magnesia	0·43
Water	11·41
Siliceous gangue	2·22
Carbonic acid and loss	0·45
	100·00

Gray Freestone, for architectural purposes, is found in a great number of places in the Pictou Coal formation, and is quarried both for domestic use and for exportation to the United States and neigh-

bouring colonies. Many buildings have been constructed of Pictou freestone in the large cities of the American Union; and its cheapness, durability, and fine colour, are likely to secure an extended demand. The principal quarries are on Saw Mill Brook, at the head of Pictou Harbour, where stone of excellent quality and colour, and both in blocks and flags, is found in great abundance. These quarries have been very extensively opened, and a railway and loading pier, three-fourths of a mile in length, have been constructed. The greatest quantity shipped in any year has been 3000 tons; but with the present facilities from 10,000 to 12,000 tons can be annually shipped from the "Acadia Quarry," which is the principal opening.

Gypsum, in workable quantity, occurs only on the East River, and is at too great a distance from a port of shipment to be quarried at present, except for domestic use.

Limestone is quarried for use in the country, at the East and West Rivers, and small quantities are occasionally taken from the beds at Merigomish and Cape John. A curious concretionary limestone, belonging apparently to the Upper Coal formation, and occurring at Fraser's Mountain and at Little Harbour, near New Glasgow, has attracted some attention as a marble for decorative purposes.

Manganese Ore, *Sulphate of Barytes*, *Umber and Ochres*, are found in small quantities. *Brick* and *Pottery* clays also occur.

The *Copper Ores* found in the Coal formation have been already mentioned. The principal localities are Caribou River, the West River, a little below Durham, and the East River, a few miles above the Albion Mines. Similar appearances also occur on French and Waugh's Rivers, in the band of Coal formation rocks connecting the Cumberland and Pictou districts. In all these places the principal ore is the gray sulphuret of the metal, with films and coatings of the green carbonate. These ores are associated with fossil plants, to which, as already explained, their accumulation is to be attributed. The ores are rich and valuable, and the only reason which prevents them from being worked, is the belief that the deposits are too limited to be of economical importance. This has been found to be the case in two instances in which trials have been made by the agents of the Mining Association. The following is the composition of a sample from Caribou, analyzed by the writer:—

Copper	40·00
Iron	11·06
Cobalt	2·10
Carry forward	53·16

Brought forward	53·16
Manganese . . .	·50
Sulphur	25·42
Carbonate of lime . .	·92
	80·00

Carboniferous District of Antigonish County.

The Pictou district is bounded on the south by an irregular tract of slaty and syenitic rocks, forming the hills of Merigomish and those extending toward Cape St George. In the coast section, the last and lowest rocks of the Pictou Carboniferous district are seen near M'Cara's Brook to rest unconformably on slates to be subsequently described, and which are of Silurian age. Passing these, towards Malignant Cove, the lower Carboniferous conglomerates and sandstones are again seen, but very much disturbed and altered by heat. It is a very instructive study to compare the soft conglomerates and their interstratified trap at M'Cara's Brook, with the continuation of the same beds eastward of Arisaig Pier, where they appear fused into hard quartzose rocks, in some of which the original texture is entirely obliterated.

The conglomerate and sandstone seen at Malignant Cove conduct us through a gap in the metamorphic hills, or round by Cape St George, to the gypsiferous rocks of the neighbourhood of Antigonish. These run along the south side of the metamorphic hills with general southerly dips, from Cape St George to the western extremity of this district, and exhibit a very large development of the gypsums and limestones, the latter containing some of the fossils already noticed in other localities.

At Cape St George, the Lower Carboniferous conglomerates appear to be largely developed, and associated with these there are sandstones and shales containing fossil plants, and also a bed of gypsum.

I am indebted to Dr Honeyman for specimens of these shales, showing *Lepidodendron corrugatum*, the most characteristic plant of the Lower Carboniferous Coal measures, and a stipe of *Cyclopteris Acadica*. They also hold scales of *Acrolepis* and *Palæoniscus*. The shale and the fossils are precisely similar to those of Horton Bluff. Similar shales occur farther to the westward, holding the same fossils, and are stated to be so rich in bituminous matters that hopes are entertained of utilizing them as a source of coal oil. The beds noticed below as occurring in Right's River, are probably of the same age. In the vicinity of Morristown there are red sandstones, conglomerate,

and gray sandstone, the latter containing *Calamites*, *Sternbergia*, and other Coal formation fossils, and no doubt higher in the series than the beds last mentioned. Near Morristown these beds dip to the N.E., and have been disturbed by a spur of trappean or altered rock, containing kernels of epidote, and associated with contorted dark shales, probably Lower Carboniferous. Beyond this interruption, the coast shows soft reddish sandstones and shales, with some beds of gray sandstone and conglomerate, dipping to the S.S.E. at an angle of 50°, and on these rests a bed of limestone nearly 100 feet thick; in its lower portion laminated, the laminæ being occasionally broken up so as to give it a fragmentary or brecciated appearance; in its upper part compact, and penetrated by small gypsum veins. On this limestone rests a rock consisting of alternate layers of limestone and gypsum, above which is a great thickness of pure flesh-coloured crystalline gypsum, and on this again, white laminated fine-grained gypsum, with minute grains of carbonate of lime. The whole thickness of the gypsum is about 200 feet, and it forms a beautiful cliff fronting the sea (Fig. 138).

Fig. 138.—*Cliff of Crystalline Gypsum near Ogden's Lake, Sydney County.*

This gypsum and limestone can be traced with scarcely any interruption to the village of Antigonish, about five miles distant, where the same beds are seen in the banks of Right's River. Near the mouth of this river, at the head of Antigonish Harbour, is a thick bed of white gypsum, dipping to the south-west. Succeeding this, in descending order, after a small interval (which appears to have been occupied by sandstones, now nearly removed by denudation), is a bed of dark-coloured limestone, in which, at different points where it

appears, I found *Productus semireticulatus*, with other shells, also occurring in the East River; and *Productus cora*, a shell not yet met with in the East River limestones, but very characteristic of the gypsiferous formation in other parts of the province. Below this limestone there is another break, also showing traces of sandstones and a bed of gypsum, and then a thick bed of dark limestone, partly laminated and partly brecciated, without fossils, and containing in its fissures thin plates of copper-ore. Beneath this limestone is a great thickness of reddish conglomerate, composed of pebbles of igneous and metamorphic rocks, and varying in texture from a very coarse conglomerate to a coarse-grained sandstone. In one place it contains a few beds of dark sandstones and shales. These are succeeded by red, gray, and dark sandstone and dark shales, in a disturbed condition, but probably underlying the conglomerate. They contain a few fossil plants, especially a *Lepidodendron* which appears to be identical with the species already mentioned as found in a similar geological position at Horton and Noel. The limestones, with their characteristic fossils, may be seen still farther west on the West River of Antigonish.

Dr Honeyman has recently discovered the pygidium of a *Phillipsia* in these limestones, being the second instance of the occurrence of Trilobites in the Lower Carboniferous of Nova Scotia. He has also, in the Transactions of the Nova Scotia Institute, published an interesting paper on the Geology of Antigonish County, in which he more accurately than heretofore defines the limits of the formation. I have availed myself of this paper in correcting the geological map in this edition.

On the west side of the Ohio River, about fifteen miles from Antigonish, this Carboniferous district terminates against the metamorphic hills, which here occupy a wide surface, and send off a long branch to Cape Porcupine in the Strait of Canseau. This branch consists in great part of slates older than the Carboniferous system, but it also appears to contain altered Carboniferous rocks. It bounds this district on the south. Along its northern side, the Lower Carboniferous limestones and gypsum appear at the north end of Lochaber Lake, at the South River, and at the northern end of the Strait of Canseau. They are probably continuous, or nearly so, between these points. In the coast between the place last mentioned and Antigonish, Carboniferous rocks, principally sandstones, appear in several places; and towards Pomket and Tracadie, in the central part of the district, the Coal formation, probably its lower portion, is seen; and small seams of coal have been found in it. I have had no opportunity of examining them, but have no doubt that they form the southern edge of the coal-field

underlying St George's Bay, and the eastern side of which appears at Port Hood in Cape Breton.

The Antigonish area thus appears to be of triangular form, with the Lower Carboniferous beds extending along its western and south-eastern sides, and the Coal formation occupying a limited space on the northern side. It is rich in limestone and gypsum, and has that fertile calcareous soil which so generally prevails over the rocks of the gypsiferous series.

Coal and Salt of Antigonish County.

Until recently it was supposed that all the Carboniferous rocks in the vicinity of Antigonish Harbour were referable to the Lower Carboniferous; but I learn from a manuscript report of Mr J. Campbell, kindly communicated to me by Mr Chisholm of Antigonish, that a limited, though productive, coal-field has been discovered in the vicinity of South Lake Brook, extending north-easterly from the road to Malignant Cove. On the south side of the area the beds dip to the northward at angles of 30° to 40°, and are underlaid on the south by Lower Carboniferous bituminous limestones and shales. The northern side of the area has not been explored, but the Coal measures must be limited in this direction by the Lower Carboniferous and igneous rocks occupying the coast from Malignant Cove to Cape St George. It would appear from Mr Campbell's report that five beds of coal have been discovered as follows, in ascending order:—

1.	*Coal*	2 ft.
	Shale	3 "
	Coal	6 "
	Beds, unknown	150 "
2.	*Coal*	9 " 5 in.
	Beds, unknown	280 "
3.	*Coal*	3 " 6 in.
	Beds—thickness not ascertained.	
4.	*Coal*	4 ft. to 6 ft.
	Beds, thickness not ascertained.	
5.	*Coal*	4 ft. or more.

The precise quality of the coal has not been ascertained, but specimens shown to me much resembled that of the Richmond Mine, or of the Lower beds at Pictou.

Brine Springs.—Salt springs arise from some parts of the Lower Carboniferous rocks, which have caused boring operations to be undertaken for brine, with good prospects of success In a boring

made, under the superintendence of Mr J. Deacon of Halifax, near the harbour landing-place, to the depth of 154 feet, the rock penetrated was gypseous marl with thin bands of limestone. After passing through about 122 feet of this material, and a bed of limestone 1 foot 2 inches thick, a bed of gypsum was reached from which a flow of strong brine entered the bore hole. The gypsum has been penetrated to the depth of eighteen feet, and is probably one of the thick beds above referred to. The brine is said to be copious and rich in salt.

Carboniferous District of Guysborough.

This district is separated from that last described by a narrow belt of metamorphic country forming a range of low elevations. Part of these altered rocks may belong to the Lower Carboniferous series itself, but the greater part of them are of higher antiquity. On the south side of this ridge, we find a belt of Carboniferous rocks, extending from the Strait of Canseau along the north side of Chedabucto Bay. Westward of the head of this bay, the Carboniferous rocks extend in a narrow band, separating the inland metamorphic hills from those of the Atlantic coast, almost as far as the sources of the west branch of the St Mary's River, fifty miles west of Chedabucto Bay.

North of the town of Guysborough, and not very far from the metamorphic rocks, is a bed of blackish laminated limestone. I could find no fossils in it, but it has the character of the lowest Carboniferous limestones as seen elsewhere. It has some of its fissures filled with micaceous specular iron, and is associated with conglomerate and sandstone somewhat altered. This limestone dips N. 60° W. at a high angle. Limestone re-appears with a high easterly dip on the opposite side of the harbour, and near it are altered shales nearly in a vertical position. Southward of the town of Guysborough, limestone again appears in thick beds, and between it and the town are reddish sandstones and conglomerates dipping S. 60° E. Some of these beds are evidently made up of the debris of the granite-hills to the southward, proving that these older hills were land undergoing waste in the Carboniferous period.

The whole of the beds near Guysborough Harbour are much disturbed and in part altered; and, immediately to the westward of the town, a spur of porphyritic and trappean rock extends from the hills to the northward, nearly across the Carboniferous valley: the eruption of these igneous rocks has probably occurred in the Carboniferous period, and effected much of the baking and other alteration which the rocks of that period have experienced.

Beyond this ridge of igneous rock, the long valley extending to

the westward is occupied by gray and reddish sandstones and conglomerate, with gray shales in a few places, the whole forming a narrow trough. On the southern margin of this trough, the conglomerate contains pebbles of gray quartzite, micaceous flag, and blue slate, precisely similar to the metamorphic rocks immediately to the southward, and in these conglomerates and the sandstones resting on them, I found a few fragments of *Calamites* and *Lepidodendron*. Fossils appear, however, to be rare in this district, and I have not observed in it any coal; nor do the limestones appear, so far as I am aware, west of Guysborough.

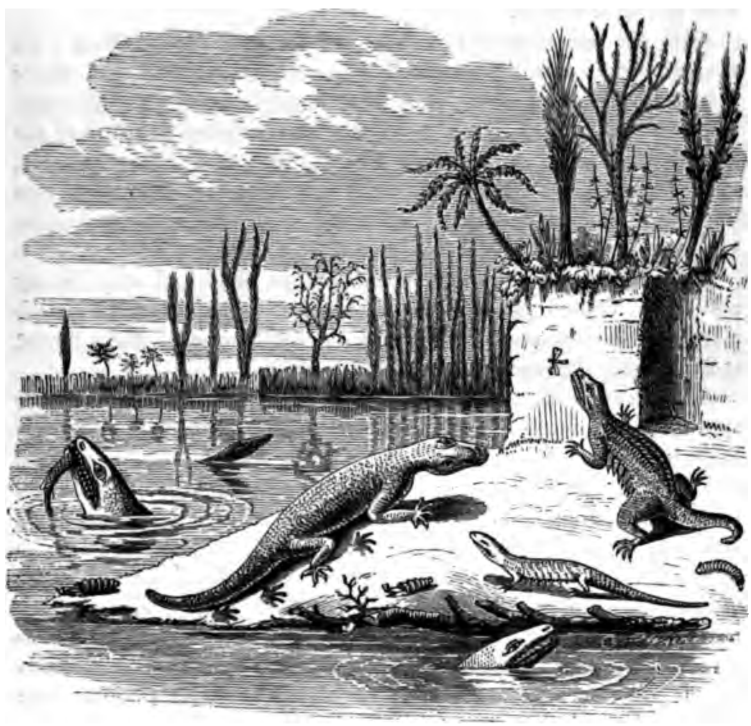
With the exception of limestone and freestone for building, I am not aware that this district affords any useful minerals. *Galena*, or sulphuret of lead, is said to have been found in small quantities near Guysborough, and small veins of *Specular Iron* traverse many of the altered rocks in that vicinity. The soils of this valley, however, especially on the St Mary's River, are causing it to rise rapidly in importance as an agricultural district, and its scenery is in many places varied and beautiful.

Before passing to the coal-fields of Cape Breton, I may shortly notice two limited patches of Carboniferous rocks occurring on the margin of the metamorphic rocks on the south coast of Nova Scotia, at Margaret's Bay and Chester Basin.

At Margaret's Bay, red and gray sandstones and a bed of limestone appear, though much buried under masses of granitic drift. In limestone from this place, I have found the *Terebratula sacculus*, a characteristic Lower Carboniferous shell. At Chester Basin, the Lower Carboniferous rocks appear still more distinctly, and contain thick beds of limestone of various qualities. One of the beds is said to be a good hydraulic cement, and another, in weathering, leaves an *umber* of a rich brown colour, which is manufactured and sold under the name of Chester mineral paint. The limestone at this place contains several of the shells already mentioned as characteristic of the Carboniferous system. A small seam of coal is also stated to occur near Chester; but I have not seen it.

These isolated patches are interesting, as they are evidently portions of the margin of a Carboniferous district either sunk beneath the Atlantic or removed by the action of its waves.

REPTILES OF THE COAL PERIOD.



RESTORATIONS OF BAPHETES, DENDRERPETON, HYLONOMUS, AND HYLERPETON.

CHAPTER XVIII.

THE CARBONIFEROUS SYSTEM—*Continued.*

LAND ANIMALS OF THE COAL PERIOD.

IN the Carboniferous period, though land plants abound, air-breathing animals are few, and most of them have only been recently recognised. We know, however, with certainty that the dark and luxuriant forests of the coal period were not destitute of animal life. Reptiles crept under their shade, land snails and millipedes fed on the rank leaves and decaying vegetable matter, and insects flitted through the air of the sunnier spots. Great interest attaches to these creatures; perhaps the first-born species in some of their respective types, and certainly belonging to one of the oldest land faunas, and presenting prototypes of future forms equally interesting to the geologist and the zoologist.

It has happened to the writer of these pages to have had some share in the discovery of several of these ancient animals. The Coal formation of Nova Scotia, so full in its development, sò rich in fossil remains, and so well exposed in coast cliffs, has afforded admirable opportunities for such discoveries, which have been so far improved that at least nine out of the not very large number of known Carboniferous reptiles, have been obtained from it. I propose in this chapter to give a general account of these interesting creatures, referring the reader for more full details to my special publication on the subject, "The Air-breathers of the Coal Period." *

Footprints.

It has often happened to geologists, as to other explorers of new regions, that footprints on the sand have guided them to the inhabitants of unknown lands. The first trace ever observed of reptiles in the Carboniferous system, consisted of a series of small but well-marked footprints found by Sir W. E. Logan, in 1841, in the Lower Coal measures of Horton Bluff, in Nova Scotia; and as the authors of all our general works on geology have hitherto, in so far as I am

* Montreal and London, 1863.

aware, failed to do justice to this discovery, I shall notice it here in detail. In the year above mentioned, Sir William, then Mr Logan, examined the coal-fields of Pennsylvania and Nova Scotia, with the view of studying their structure, and extending the application of the discoveries as to *Stigmaria* underclays which he had made in the Welsh coal-fields. On his return to England, he read a paper on these subjects before the Geological Society of London, in which he noticed the discovery of reptilian footprints at Horton Bluff. The specimen was exhibited at the meeting of the Society, and was, I believe, admitted on the high authority of Prof. Owen, to be probably reptilian. Unfortunately, Sir William's paper appeared only in abstract in the Transactions; and in this abstract, though the footprints are mentioned, no opinion is expressed as to their nature. Sir William's own opinion is thus stated in a letter to me, dated June 1843, when he was on his way to Canada, to commence the survey which has since developed so astonishing a mass of geological facts:—

"Among the specimens which I carried from Horton Bluff, one is of very high interest. It exhibits the footprints of some reptilian animal. Owen has no doubt of the marks being genuine footprints. The rocks of Horton Bluff are below the gypsum of that neighbourhood; so that the specimen in question (if Lyell's views are correct*) comes from the very bottom of the coal series, or at any rate very low down in it, and demonstrates the existence of reptiles at an earlier epoch than has hitherto been determined; none having been previously found below the magnesian limestone, or, to give it Murchison's new name, the 'Permian era.'"

This extract is of interest, not merely as an item of evidence in relation to the matter now in hand, but as a mark in the progress of geological investigation. For the reasons above stated, the important discovery thus made in 1841, and published in 1842, was overlooked; and the discovery of reptilian bones by Von Dechen, at Saarbruck, in 1844, and that of footprints by Dr King in the same year, in Pennyslvania, have been uniformly referred to as the first observations of this kind. This error I now desire to correct, not merely in the interest of truth, but also in that of my friend Sir William Logan, and of my native province of Nova Scotia; and I trust that henceforth the received statement will be, that the first indications of the existence of reptiles in the coal period were obtained by Logan, in the Lower Coal formation of Nova Scotia, in 1841. Insects and arachnidans, it

* Sir Charles Lyell had then just read a paper announcing his discovery that the gypsiferous system of Nova Scotia is Lower Carboniferous, in which he mentions the footprints referred to as being reptilian.

may be observed, had previously been discovered in the Coal formation in Europe.

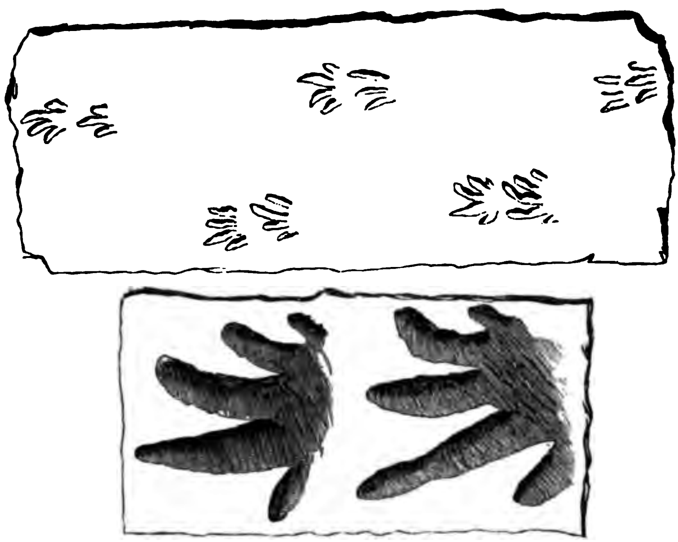
The original specimen of these footprints is still in the collection of Sir William Logan. It is a slab of dark-coloured sandstone, glazed with fine clay on the surface; and having a series of seven footprints in two rows, distant about three inches; the distance of the impressions in each row being three or four inches, and the individual impressions about one inch in length. They seem to have been made by the points of the toes, which must have been armed with strong and apparently blunt claws, and appear as if either the surface had been somewhat firm, or as if the body of the animal had been partly water-borne. In one place only is there a distinct mark of the whole foot, as if the animal had exerted an unusual pressure in turning or stopping suddenly. One pair of feet, the fore feet I presume, appear to have had four claws; the other pair may have had three or four, and it is to be observed that the outer toe, as in the larger footprints discovered by Dr King, projects in the manner of a thumb, as in the cheirotherian tracks of the Trias. No mark of the tail or belly appears. The impressions are such as may have been made by some of the reptiles to be described in the sequel, as, for instance, by *Dendrerpeton Acadianum.*

Attention having been directed to such marks by these observations of Sir William Logan, several other discoveries of the same kind were subsequently made in various parts of the province, and in different members of the Carboniferous system. The first of these, in order of time, was made in 1844, in beds of red sandstone and shale near Tatamagouche, in the eastern part of Nova Scotia, and belonging to the Upper or newer members of the Coal measures. In examining these beds with the view of determining their precise geological age, I found on the surface of some of them impressions of worm-burrows, rain-drops, and sun-cracks, and with these, two kinds of footprints, probably of reptilian animals. One kind consisted of marks, or rather scratches, as of three toes, and resembling somewhat the scratches made by the claws of a tortoise in creeping up a bank of stiff clay; they were probably of the same nature and origin with those found by Logan at Horton. The others were of very different appearance. They consisted of two series of strongly marked elongated impressions, without distinct marks of toes, in series four inches distant from each other, and with an intervening tail mark. They seem to have been produced by an animal wading in soft mud, so that deep holes, rather than regular impressions, marked its footsteps, and that in the hind foot the heel touched the surface, giving

a plantigrade appearance to the tracks. Rain-marks had been impressed on the surface after the animal had passed over it, and these had probably aided in obliterating the finer parts of the impressions. These observations were published in the Journal of the Geological Society of London, vols. 1 and 2.

Shortly afterward, Dr Harding of Windsor, when examining a cargo of sandstone which had been landed at that place from Parrsboro', found on one of the slabs a very distinct series of footprints, each with four toes, and a trace of the fifth (Fig. 139). Dr Harding's specimen

Fig. 139.—*Footprints of Dendrerpeton (?) from Parrsboro',—slab with footprints reduced, and two impressions, natural size.*



is now in the museum of King's College, Windsor. Its impressions are more distinct, but not very different otherwise, from those above described as found at Horton Bluff. The rocks at that place are probably of nearly the same age with those of Parrsboro'. I afterwards examined the place from which this slab had been quarried, and satisfied myself that the beds are Carboniferous, and probably Lower Carboniferous. They were ripple-marked and sun-cracked, and I thought I could detect trifid footprints, though more obscure than those in Dr Harding's slab. Similar footprints are also stated to have been found by Dr Gesner, at Parrsboro'. In these Parrsboro' beds Mr Jones, F.L.S., has recently found a series of larger footprints

referable to the genus *Sauropus*, to be subsequently mentioned in connexion with the discovery of similar footprints in Cape Breton.

I have since observed several instances of such impressions at the Joggins, at Horton, and near Windsor, showing that they are by no means rare, and that reptilian animals existed in no inconsiderable numbers throughout the coal-field of Nova Scotia, and from the beginning to the end of the Carboniferous period. Two examples are figured in my "Air-breathers," with those already described. On comparing these with one another, it appears that Logan's, Harding's, and one of mine are of similar general character, and may have been made by one kind of animal, which must have had the fore and hind feet nearly of equal size. The other belongs to a smaller animal, which probably travelled on longer limbs, more in the manner of an ordinary quadruped. Its toes cannot be distinguished. On the whole, these footprints, while differing from those found by Dr King in Pennsylvania, do not prove the existence of any kind of animal distinct from those to be described in the sequel, and known to us by the preservation of portions of their skeletons.

The study of these footprints shows that the animals which produced them may, in certain circumstances, have left impressions of only two or three of their toes, while in other circumstances all may have left marks; and that, when wading in deep mud, their footprints were altogether different from those made on hard sand or clay. In some instances the impressions may have been made by animals wading or swimming in water, while in others the rain-marks and sun-cracks afford evidence that the surface was a sub-aërial one. They are chiefly interesting as indicating the wide diffusion and abundance of the creatures producing them, and that they haunted tidal flats and muddy shores, perhaps emerging from the water that they might bask in the sun, or possibly searching for food among the rejectamenta of the sea, or of lagoons and estuaries.

Mr Brown of Sydney has added to our knowledge of Carboniferous footprints by the discovery of a fine slab, now in the museum of M'Gill University, which indicates the existence of an animal of considerable size, the breadth of the foot being three inches (Fig. 140). The specimen was thus described by the writer in the "Canadian Naturalist:"—

"The slab exhibits with some distinctness three footprints of the right side, and less distinct traces of the left feet. The feet are short and broad, the fore foot as large as the hind foot, the toes short, broad, and deeply impressed in the sand. Four toes are distinctly marked in both fore and hind feet, and there are indications of a fifth in one

of the footprints. The stride is considerably greater than the breadth of the body. The toes are somewhat turned inward. The figure is reduced to one-sixth, so that the animal must have been rather larger than *Dendrerpeton Acadianum*, with shorter toes and broader body."

Fig. 140.—*Footprints of Sauropus Sydnensis* (*reduced*).

These footprints are quite different in form from those previously found by Sir W. E. Logan, Dr Harding, and the writer. They more nearly resemble those figured by Dr King and Mr Lea from the Carboniferous of Pennsylvania; and may have been produced by an animal generically related to that which has left the traces named *Sauropus primævus* by the latter author. For this reason, until we shall obtain some knowledge of the animal from more definite remains, I propose for it the name of *Sauropus Sydnensis*. The specimen was found by Mr Brown in the Coal formation at North Sydney.

These footprints add a ninth species to the reptilian fauna of the Coal formation of Nova Scotia, and are the first traces of this kind discovered in the Cape Breton Coal-field.

The footprint already mentioned as having been found by Mr Jones of Halifax at Parrsboro', is almost precisely of the same size and form with the preceding, and may possibly have belonged to the same species. It has five distinctly marked toes.

Baphetes planiceps, Owen.

In the summer of 1851, I had occasion to spend a day at the Albion Mines; and on arriving at the railway station in the afternoon, found myself somewhat too early for the train. By way of improving the time thus left on my hands, I betook myself to the examination of a large pile of rubbish, consisting of shale and ironstone from one of the pits, and in which I had previously found scales and teeth of fishes. In the blocks of hard Carbonaceous shale and earthy coal, of which the pile chiefly consisted, scales, teeth, and coprolites often appeared on the weathered ends and surfaces as whitish spots. In looking for these, I observed one of much greater size than usual, on the edge of a block, and on splitting it open, found a large flattened skull, the cranial bones of which remained entire on one side of the mass, while the palate and teeth, in a more or less fragmentary state, came away with the other half. Carefully trimming the larger specimen, and gathering all the smaller fragments, I packed them up as safely as possible, and returned from my little excursion much richer than I had hoped.

The specimen, on further examination, proved somewhat puzzling. I supposed it to be, most probably, the head of a large ganoid fish; but it seemed different from anything of this kind with which I could compare it; and at a distance from comparative anatomists, and without sufficient means of determination, I dared not refer it to anything higher in the animal scale. Hoping for further light, I packed it up with some other specimens, and sent it to the Secretary of the Geological Society of London, with an explanatory note as to its geological position, and requesting that it might be submitted to some competent osteologist for examination. For a year or two, however, it remained as quietly in the Society's collection as if in its original bed in the coal-mine, until attention having been attracted to such remains by the discoveries made by Sir Charles Lyell and myself in 1852, at the South Joggins, and published in 1853,* the Secretary or President of the Society rediscovered the specimen, and handed it to Professor Owen, by whom it was described in December 1853,† under the name of *Baphetes planiceps*, which may be interpreted the "flat-headed-diving animal," in allusion to the flatness of the creature's skull, and the possibility that it may have been in the habit of diving.

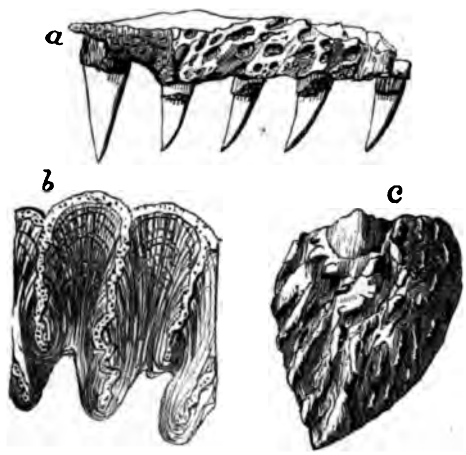
The parts preserved in my specimen are the bones of the anterior and upper part of the skull in one fragment, and the teeth and palatal bones in others (see Fig. 137, *ante;* also Fig. 141). The teeth are

* Journal of Geological Society of London, vol. ix.

† Journal of Geological Society, vol. x.; and additional notes, vol. xi.

conical and somewhat curved, the outer series from a line to two lines in diameter, and the inner series three lines or more. They are implanted in shallow sockets in the maxillary and premaxillary bones, and are anchylosed to the sockets. For the lower third, the outer surface presents shallow vertical grooves, conformably with the plicated character of the internal structure. The upper portion is smooth, and its internal structure presents merely radiating tubes of ivory, and concen-

Fig. 141.—*Baphetes planiceps*, Owen.



(*a*) Fragment of maxillary bone showing sculpture, four outer teeth, and one inner tooth; nat. size. (*b*) Section of inner tooth; magnified. (*c*) Dermal scale; nat. size.

tric layers. The whole of these characters are regarded as allying the animal with the great crocodilian frogs of the Trias of Europe, first known as *Cheirotherians*, owing to the remarkable hand-like impressions of their feet, and afterwards as *Labyrinthodonts*, from the beautifully complicated convolutions of the ivory of their teeth.

The only additional remains attributable to this creature, found since the publication of Professor Owen's description, are a bone and a scute or scale. The former may be a scapular or sternal bone, and if so, would warrant the belief that the creature possessed anterior limbs of considerable size; the proportion relatively to the skull being much the same as in the American bullfrog. The latter is marked in the same way as the bones of the head, and would indicate that *Baphetes* was protected by bony dermal scales, resembling those of the crocodile.

Of the general form and dimensions of *Baphetes*, the facts at present known do not enable us to say much. Its formidable teeth and

strong maxillary bones show that it must have devoured animals of considerable size, probably the fishes whose remains are found with it, or the smaller reptiles of the coal. It must, in short, have been crocodilian, rather than frog-like, in its mode of life; but whether, like the labyrinthodonts, it had strong limbs and a short body, or like the crocodiles, an elongated form and a powerful natatory tail, the remains do not decide. One of the limbs, or a vertebra of the tail, would settle this question, but neither has as yet been found. That there were large animals of the labyrinthodontal form in the Coal period, is proved by the footprints of *Sauropus*, already noticed, which may have been produced by an animal of the type of *Baphetes*. On the other hand, that there were large swimming reptiles seems established by the recent discovery of the vertebræ of *Eosaurus Acadianus*, at the Joggins, by Mr Marsh.* The locomotion of *Baphetes* must have been vigorous and rapid, but it may have been effected both on land and in water, and either by feet or tail, or both.

With the nature of its habitat we are better acquainted. The area of the Albion Mines Coal-field was somewhat exceptional in its character. It seems to have been a bay or indentation in the Silurian land, separated from the remainder of the coal-field by a high shingle beach, now a bed of conglomerate. Owing to this circumstance, while in the other portions of the Nova Scotia Coal-field the beds of coal are thin, and alternate with sandstones and shales, at the Albion Mines a vast thickness of almost unmixed vegetable matter has been deposited, constituting the "main seam" of thirty-eight feet thick, and the "deep seam" twenty-four feet thick, as well as still thicker beds of highly carbonaceous shale. But, though the area of the Albion Coal measures was thus separated, and preserved from marine incursions, it must have been often submerged, and probably had connexion with the sea, through rivers or channels cutting the enclosing beach. Hence beds of earthy matter occur in it, containing remains of large fishes. One of the most important of these is that known as the "Holing stone,"—a band of black highly carbonaceous shale, coaly matter, and clay ironstone, occurring in the main seam, about five feet below its roof, and varying in thickness from two inches to nearly two feet. It was from this band that the rubbish-heap in which I found the skull of *Baphetes planiceps* was derived. It is a laminated bed, sometimes hard and containing much ironstone, in other places soft and shaly; but always black and carbonaceous, and often with layers of coarse coal, though with few fossil plants retaining their forms. It contains large round flat scales and flattened curved teeth,

* Silliman's Journal, 1859.

which I attribute to a fish of the genus *Rhizodus*, resembling, if not identical with, *R. lancifer*, Newberry. With these are double-pointed shark-like teeth, and long cylindrical spines of a species of *Diplodus* (*D. acinaces*).* There are also shells of the minute *Spirorbis*, so common in the Coal measures of other parts of Nova Scotia, and abundance of fragments of coprolitic matter.

It is evident that the "Holing stone" indicates one of those periods in which the Albion Coal area, or a large part of it, was under water, probably fresh or brackish, as there are no properly marine shells in this or any of the other beds of this Coal series. We may then imagine a large lake or lagune, loaded with trunks of trees and decaying vegetable matter, having in its shallow parts, and along its sides, dense brakes of *Calamites*, and forests of *Sigillaria*, *Lepidodendron*, and other trees of the period, extending far on every side as damp pestilential swamps. In such a habitat, uninviting to us, but no doubt suited to *Baphetes*, that creature crawled through swamps and thickets, wallowed in flats of black mud, or swam and dived in search of its finny prey.

Dendrerpeton Acadianum, Owen.

The geology of Nova Scotia is largely indebted to Sir Charles Lyell. Though much had previously been done by others, his personal explorations in 1842, and his paper on the gypsiferous formation, published in the following year, first gave form and shape to some of the more difficult features of the geology of the country, and brought it into relation with that of other parts of the world. In geological investigation, as in many other things, patient plodding may accumulate large stores of fact, but the magic wand of genius is required to bring out the true value and significance of these stores of knowledge. It is scarcely too much to say that the explorations of a few weeks, and subsequent study of the subject by Sir Charles, with the impulse and guidance given to the labours of others, did as much for Nova Scotia as might have been effected by years of laborious work under less competent heads.

Sir Charles naturally continued to take an interest in the geology of Nova Scotia, and to entertain a desire to explore more fully some of those magnificent coast sections which he had but hastily examined; and when, in 1851, he had occasion to revisit the United States, he made an appointment with the writer of these pages to spend a few days in renewed explorations of the cliffs of the South Joggins. The object specially in view was the thorough examination of the beds of

* See pp. 202, 203, *ante*.

the true Coal measures, with reference to their contained fossils, and the conditions of accumulation of the coal; and the results were given to the world in a joint paper on "The Remains of a Reptile and a Land-shell discovered in the Interior of an erect Tree in the Coal Measures of Nova Scotia," and in the writer's paper on "The Coal Measures of the South Joggins;"* while other important investigations grew out of the following up of these researches, and much matter in relation to the vegetable fossils has only recently been worked out. It is with the more striking fact of the discovery of the remains of a reptile in the Coal measures that we have now to do.

These interesting remains were found in the interior of one of those fossil erect *Sigillariæ* described in a previous chapter, and which, having fallen from the cliff, lay in large disc-like fragments on the beach. While examining these "fossil grindstones," we were surprised by finding on one of them what seemed to be fragments of bone. On careful search, other bones appeared, and they had the aspect, not of remains of fishes, of which many species are found fossil in these Coal measures, but rather of limb-bones of a quadruped. The fallen pieces of the tree were carefully taken up, and other bones disengaged, and at length a jaw with teeth made its appearance. We felt quite confident, from the first, that these bones were reptilian; and the whole being carefully packed and labelled, were taken by Sir Charles to the United States, and submitted to Professor J. Wyman of Cambridge, who recognised their reptilian character, and prepared descriptive notes of the principal bones, which appeared to have belonged to two species. He also observed among the fragments an object of different character, apparently a shell, which was recognised by Dr Gould of Boston, and subsequently by Mr Deshayes, as probably a land-snail, and has since been named *Pupa vetusta*.

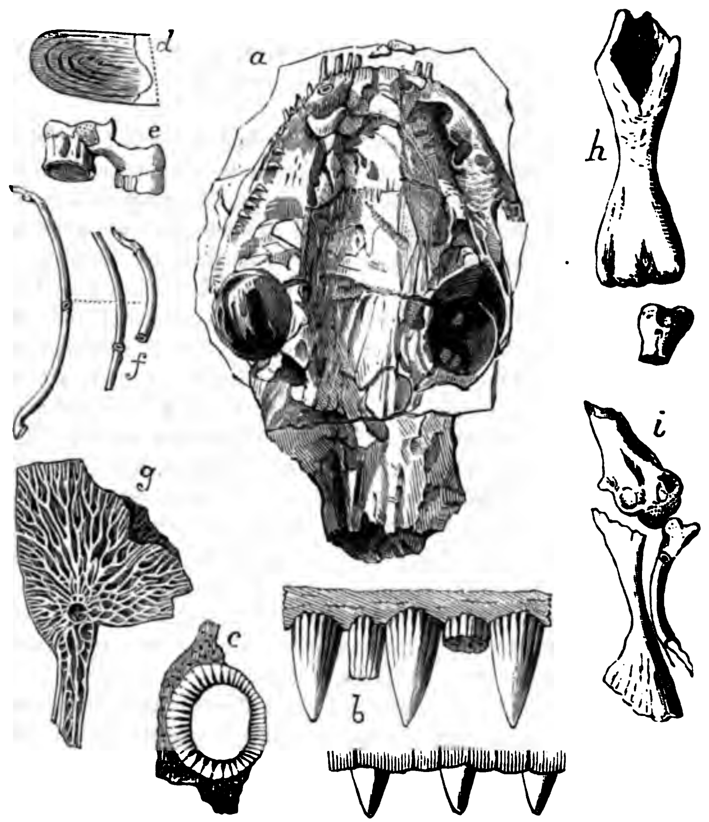
The specimens were subsequently taken to London and re-examined by Professor Owen, who confirmed Wyman's inferences, added other characters to the description, and named the larger and better preserved species *Dendrerpeton Acadianum*, in allusion to its discovery in the interior of a tree, and to its native country of Acadia or Nova Scotia (Fig. 142).

In form, *Dendrerpeton Acadianum* was probably lizard-like; with a broad flat head, short stout limbs, and an elongated tail; and having its skin, and more particularly that of the belly, protected by small bony plates closely overlapping each other. It may have attained the length of two feet. The form of the head is not unlike that of

* Journal of the Geological Society of London, vols. ix. and x.

Baphetes, but longer in proportion; and much resembles that of the labyrinthodont reptiles of the Trias. The bones of the skull are sculptured as in *Baphetes*, but in a smaller pattern. The nostrils are small, and near the muzzle; the orbits are circular, and separated by

Fig. 142.—*Dendrerpeton Acadiunum*, Owen.



(*a*) Skull; natural size.
(*b*) Teeth, inner and outer series; magnified.
(*c*) Section of one of the outer series; magnified.
(*d*) Bony scale; enlarged.
(*e*) Vertebra; natural size.
(*f*) Ribs; natural size.
(*g*) Cranial bone, showing sculpture.
(*h*) Humerus and ulna; natural size.
(*i*) Distal end of femur and portion of tibia and fibula; natural size.

a space of more than their own diameter. In the upper jaw there is a series of conical teeth on the maxillary and intermaxillary bones. Those on the intermaxillaries are much larger than the others, and have the aspect of tusks or canines. Within this outer series of teeth,

but implanted apparently in the same bones, there is a second series of teeth, closely placed, or with intervals equal to the diameter of one tooth. These inner teeth are longer than the others, implanted in shallow sockets, to which they are anchylosed, and have the dentine plicated, except toward the point. A third group of teeth, blunt at the points, largely hollow in the interior, and with the dentine quite simple, appears in detached bones, which may represent the vomer. Only a part of this formidable armature of teeth appears in the skull represented in Fig. 142, as the bones of the roof of the mouth have been removed, adhering to the opposite side of the matrix. It will be observed that all these teeth are anchylosed to the bone; and that those of the vomer are thinly walled and simple, the outer series on the maxillaries and intermaxillaries simple and flattened, while the inner series of teeth are conical and plicated. In the lower jaw there was a uniform series of conical teeth, not perceptibly enlarged toward the front, and an inner series of larger and plicated teeth, as in the upper jaw.

The scapular and sternal bones seem to have been well developed and strong, but only portions of them are known. The fore limb of the adult animal, including the toes, must have been four or five inches in length, and is of massive proportions. The bones were hollow, and in the case of the phalanges the bony walls were thin, so that they are often found crushed flat. The humerus, however, was a strong bone, with thick walls and a cancellated structure toward its extremities; still, even these have sometimes yielded to the great pressure to which they have been subjected. Fig. 142 shows the humerus of the original specimen of the species. The cavity of the interior of the limb-bones is usually filled with calc-spar stained with organic matter, but showing no structure; and the inner side of the bony wall is smooth, without any indication of cartilaginous matter lining it.

The vertebræ, in the external aspect of their bodies, remind one of those of fishes, expanding toward the extremities, and being deeply hollowed by conical cavities, which appear even to meet in the centre. There is, however, a large and flattened neural spine. The vertebræ are usually much crushed, and it is almost impossible to disengage them from the stone. Fig. 142 exhibits the usual form, and there are others with long spines above and below, reminding us of those of the batrachians and reptiles which have tails flattened for swimming, and probably indicating that this was the case with *Dendrerpeton*. The ribs are long and curved, with an expanded head, near to which they are solid, but become hollow toward the middle; and the distal

extremities are flattened and thin walled. The posterior limb seems to have been not larger than the anterior, perhaps smaller. The bones represented in Fig. 142, which I refer to this member, probably belonged to a somewhat smaller individual than that to which the humerus above mentioned belonged. The tibia is much flattened at the extremity, as in some labyrinthodonts, and the foot must have been broad, and probably suited for swimming or walking on soft mud, or both. That the hind limb was adapted for walking is shown, not merely by the form of the bones, but also by that of the pelvis.

The external scales are thin, oblique-rhomboidal or elongated oval, marked with slight concentric lines, but otherwise smooth, and having a thickened ridge or margin; in which they resemble those of *Archegosaurus*, and also those of *Pholidogaster pisciformis*, recently described by Huxley from the Edinburgh Coal-field,—an animal which indeed appears in most respects to have a close affinity with *Dendrerpeton*. The microscopic structure of the scales is quite similar to that of the other bones, and different from that of the scales of ganoid fishes. In one of the specimens the scales of the throat remain in their natural position, and are seen to be of a narrow ovate form, and arranged in imbricated rows diverging from the mesial line.

This ancient inhabitant of the coal swamps of Nova Scotia was, in short, as we often find to be the case with the earliest forms of life, the possessor of powers and structures not usually, in the modern world, combined in a single species. It was certainly not a fish, yet its bony scales, and the form of its vertebræ and of its teeth might, in the absence of other evidence, cause it to be mistaken for one. We call it a batrachian, yet its dentition, the sculpturing of the bones of its skull, which were certainly no more external plates than the similar bones of a crocodile, its ribs, and the structure of its limbs, remind us of the higher reptiles; and we do not know that it ever possessed gills, or passed through a larval or fish-like condition. Still, in a great many important characters its structures are undoubtedly batrachian. It stands, in short, in the same position with the *Lepidodendra* and *Sigillariæ* under whose shade it crept, which, though placed by palæobotanists in alliance with certain modern groups of plants, manifestly differed from these in many of their characters, and occupied a different position in nature. In the Coal period, the distinctions of physical and vital conditions were not well defined—dry land and water, terrestrial and aquatic plants and animals, and lower and higher forms of animal and vegetable life, are consequently not easily separated from each other. This is no doubt a state of things characteristic of the earlier stages of the earth's history, yet not necessarily so; for there

are some reasons, derived from fossil plants, for believing that in the preceding Devonian period there was less of this, and consequently that there may then have been a higher and more varied animal life than in the Coal period.* Even in the modern world also, we still find local cases of this early union of dissimilar conditions. It is in the swamps of Africa, at one time dry, at another inundated, that such intermediate forms as *Lepidosiren* occur, to baffle the classificatory powers of naturalists; and it is in the stagnant unaërated waters, half swamp, half lake or river, and unfit for ordinary fishes, that the semi-reptilian *Amia* and *Lepidosteus* still keep up the characters of their palæozoic predecessors.

The dentition of *Dendrerpeton* shows it to have been carnivorous in a high degree. It may have captured fishes and smaller reptiles, either on land or in water, and very probably fed on dead carcases as well. If, as seems likely, the footprints referred to in a previous section belong to *Dendrerpeton*, it must have frequented the shores, either in search of garbage, or on its way to and from the waters. The occurrence of its remains in the stumps of *Sigillaria*, with land-snails and millipedes, shows also that it crept in the shade of the woods in search of food; and under the head of coprolitic matter, in a subsequent section, I shall show that remains of excrementitious substances, probably of this species, contain fragments attributable to smaller reptiles, and other animals of the land.

Several of the bones of the limbs remain in sufficiently good preservation to allow of measurement of their size. I am thus enabled to give the following dimensions of parts of the animal:—

Total length of skull	2·75 inches
„ breadth of skull at the orbits	2 „
Length of humerus	1·33 inch
„ ulna	1 „
„ femur	1 „
„ rib	0·75 „
„ eleven vertebræ in series	2·25 „

It would seem from these dimensions that the head was broad and the trunk slender; the anterior limb, including the foot, half as long again as the head, and the posterior limb rather smaller or shorter than the anterior. It would thus appear that while the general form of the body was not unlike that of *Menobranchus*, the limbs were much larger, and must have carried the trunk without allowing any part of

* See the author's paper on Devonian Plants, Journal of the Geological Society, vol. xviii., p. 328.

it to touch the ground, as would also seem to have been the case from the footprints found in the Coal formation beds, and the size and form of the toes of which make it likely that they belonged to this animal.

From the relative dimensions of the bones, as compared with those of other specimens in my possession, I presume that this individual was three-fourths grown, and I doubt if its total length much exceeded one foot.

The limb-bones, though thin-walled and often crushed, evidently had broad articulating surfaces; and in the case of the fore-limbs particularly, were large and strong in proportion to the dimensions of the head and vertebral column.

The large size of the fore limb I suppose to have been related to a habit of walking or standing in shallow water, with the snout in the air, in the manner of newts, and the more rapid movements of the creature were probably performed by the tail. It is interesting to observe that in *Hylonomus* the proportions of the limbs were reversed —the hind limbs being much larger than the fore limbs.

Dendrerpeton Oweni, Dawson.

Among the reptilian remains found in erect trees at the South Joggins, there have occurred several portions of skeletons, which, from their sculptured cranial bones, plicated teeth, and the forms of their scales and limb-bones, I have referred to the genus *Dendrerpeton*, but to individuals of much smaller size than the full-grown specimens of *D. Acadianum* (Fig. 143).

On carefully examining these specimens, the result has been to establish a strong probability that there is a second species of *Dendrerpeton*, smaller than *D. Acadianum*, and differing from it in several points. This species I propose to name *D. Oweni.* It differs from *D. Acadianum* in the following particulars:—(1.) Its much smaller size; (2.) Its long and hooked teeth (it will be seen that these teeth differ very markedly in their proportions and form from those of the larger species represented in Fig. 142); (3.) The greater plication of the ivory in the intermaxillary teeth (in *D. Acadianum* these teeth are, on the outside, simple almost to the base, and plicated on the inner side, while in this species they are plicated all around like the inner maxillary teeth); (4.) The form of the skull, which has the orbit larger in proportion, and is also shorter and broader. On the other hand, when we have described the species of *Hylonomus*, it will be seen that this animal, except in size, differs from them quite as widely as does *D. Acadianum.*

The distinctness of *D. Oweni* is further confirmed by the fact that

I possess small jaw-bones of *Dendrerpeton*, about the size of those of this species, but having the teeth similar in form to those of the larger species; these I suppose to have belonged to young individuals.

The forms of the jaw-bones and of the vertebræ, ribs, scapular bone, bones of the limbs, and bony scales, indicate that in general form this creature was not far removed from its larger relative. The bones of

Fig. 143.—*Dendrerpeton Oweni*, Dawson.

(a) Maxillary bone and mandible; natural size.
(b) Portion of skull; natural size.
(c) One of the large anterior teeth; magnified.
(d) Exterior teeth; magnified.
(e) Foot; enlarged.
(f) Portion of cuticle showing horny scales; enlarged.
(g) Cuticle of posterior part of body; natural size, showing supposed position of hind leg at *b*.

the foot, represented in Fig. 143, especially deserve attention. This is the most perfect foot of *Dendrerpeton* hitherto found; and I have enlarged it in the figure in order more distinctly to show its parts. It presents three long toes, with traces of a smaller one at each side, so that there were probably five in all. If these toes be compared with the footprints on the slab discovered by Dr Harding, represented in Fig. 139, it will be seen that they very closely correspond, though

the toes of the present species are much smaller. The footprints are precisely those which we may suppose an animal of the size of *Dendrerpeton Acadianum* would have made, if, as the bones found render in every way probable, this larger species had a foot similar to that of *D. Oweni.* I suppose, for this reason, that these footprints are really those of *Dendrerpeton Acadianum;* and that this species continued to exist from the time of the Lower Coal measures to the period when those higher beds of the series in which its bones are found at the Joggins were deposited.

The present species must have lived in the same places with its larger relative; but may have differed somewhat in its habits. Its longer and sharper teeth may have been better suited for devouring worms, larvæ, or soft-skinned fishes, while those of the larger *Dendrerpeton* were better adapted to deal with the mailed ganoids of the period, or with those smaller reptiles which were more or less protected with bony or horny scales.

In one of my earliest explorations of the reptile-bearing stumps of the Joggins, I observed on some of the surfaces patches of a shining black substance, which on minute examination proved to be the remains of cuticle, with horny scales and other appendages. The fragments were preserved; but I found it impossible to determine with certainty to which of the species whose bones occur with them they belonged, or even to ascertain the precise relations of the several fragments to each other. I therefore merely mentioned them in general terms, and stated my belief that they may have belonged to the species of *Hylonomus.* More recently other specimens have been obtained, which enable me to refer these specimens in part to the present species and in part to the next species, *Hylonomus Lyelli.* The specimen represented in Fig. 143, I believe, for reasons stated in my memoir already referred to, to be the skin of a portion of the hinder part of an individual of the present species.

Hylonomus Lyelli, Dawson.

In the original reptiliferous tree discovered by Sir C. Lyell and the writer at the Joggins in 1851, there were, beside the bones of *Dendrerpeton Acadianum*, some small elongated vertebræ, evidently of a different species. These were first detected by Prof. Wyman in his examination of these specimens, and were figured, but not named, in the notice of the specimens in the Journal of the Geological Society, vol. ix. In a subsequent visit to the Joggins, I obtained from another erect stump many additional remains of these smaller reptiles, and, on careful comparison of the specimens, was induced to refer

them to three species, all apparently generically allied. I proposed for them the generic name *Hylonomus*, "forest-dweller." They were described in the Proceedings of the Geological Society for 1859, with illustrations of the teeth and other characteristic parts.* The smaller species first described I named *H. Wymani;* the next in size, that to which this article refers, and which was represented by a larger number of specimens, I adopted as the type of the genus, and dedicated to Sir Charles Lyell. The third and largest, represented only by a few fragments of a single skeleton, was named *H. aciedentatus.*

Hylonomus Lyelli was an animal of small size. Its skull is about an inch in length, and its whole body, even if, as was likely, furnished with a tail, could not have been more than six or seven inches long. No complete example of its skull has been found. The bones appear to have been thin and easily separable; and even when they remain together, are so much crushed as to render the shape of the skull not easily discernible. They are smooth on the outer surface to the naked eye, and under a lens show only delicate uneven striæ and minute dots. They are more dense and hard than those of *Dendrerpeton*, and the bone-cells are more elongated in form. The bones of the snout would seem to have been somewhat elongated and narrow. A specimen in my possession shows the parietal and occipital bones, or the greater part of them, united, and retaining their form. We learn from them that the brain-case was rounded, and that there was a parietal foramen. There would seem also to have been two occipital condyles. Several well-preserved specimens of the maxillary and mandibular bones have been obtained. They are smooth, or nearly so, like those of the skull, and are furnished with numerous sharp conical teeth, anchylosed to the jaw, in a partial groove formed by the outer ridge of the bone. In the anterior part of the lower jaw there is a group of teeth larger than the others. The intermaxillary bone has not been observed. The total number of teeth in each ramus of the lower jaw was about forty, and the number in each maxillary bone about thirty. The teeth are perfectly simple, hollow within, and with very fine radiating tubes of ivory. The vertebræ have the bodies cylindrical or hour-glass shaped, covered with a thin, hard, bony plate, and having within a cavity of the form of two cones, attached by the apices. The ribs are long, curved, and at the proximal end have a shoulder and neck. They are hollow, with thin hard bony walls. The anterior limb, judging from the fragments procured, seems to have been slender, with long toes, four or possibly five in number. The posterior limb was longer and stronger, and attached to a pelvis

* Journal of Geological Society, vol. xvi.

so large and broad as to give the impression that the creature enlarged considerably in size toward the posterior extremity of the body, and that it may have been in the habit of sitting erect. The thigh bone is well formed, with a distinct head and trochanter, and the lower extremity flattened and moulded into two articulating surfaces for the tibia and fibula, the fragments of which show that they were much shorter. The toes of the hind feet have been seen only in detached joints. They seem to have been thicker than those of the fore foot. Detached vertebræ, which seem to be caudal, have been found, but the length of the tail is unknown. The limb bones are usually somewhat crushed and flattened, especially at their articular extremities, and this seems to have led to the error of supposing that this flattened form was their normal condition; there can be no doubt, however, that it is merely an effect of pressure. The limb bones present in cross section a wall of dense bone with elongated bone-cells, surrounding a cavity now filled with brown calc-spar, and originally occupied with cartilage or marrow. Nothing is more remarkable in the skeleton of this creature than the contrast between the perfect and beautiful forms of its bones, and their imperfectly ossified condition,—a circumstance which raises the question whether these specimens may not represent the young of some reptile of larger size.

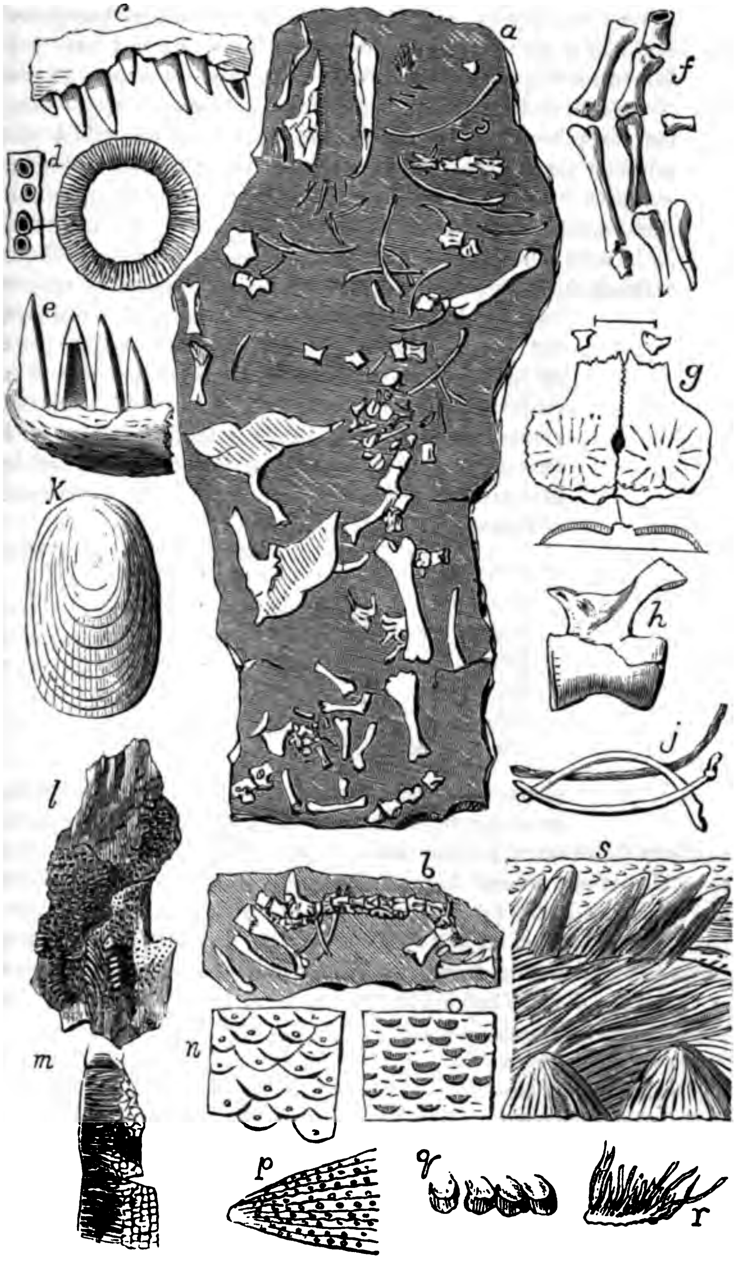
The dermal covering of this animal is represented in part by oval bony scales, which are so constantly associated with its bones that I can have no doubt that they belonged to it, being, perhaps, the clothing of its lower or abdominal parts; while above, it was probably clad in the beautiful scaly covering represented in Fig. 144,* and which shows that the creature, while probably clad with bony scales below, had on its back an array of scaly and spiny ornaments comparable with those of any modern reptile. The bony scales differ in form from those of *Dendrerpeton;* they are also much thicker. On the inner side they are concave, with a curved ledge or thickened border at one edge. On the outer side they present concentric lines of growth.

The only specimens which afford much information as to the general form of *Hylonomus Lyelli* are those represented in Fig. 144. The first is the original specimen from which I described the species in the

* *Description of Fig.* 144.

(*a*) Skeleton in matrix, showing jaws, ribs, vertebræ, pelvis, and bones of limbs.
(*b*) Portion of skeleton in matrix, showing vertebræ and limb bones.
(*c*) Portion of maxilla with teeth; enlarged.
(*d*) Cross sections of teeth; enlarged.
(*e*) Anterior end of mandible with teeth; enlarged.
(*f*) Bones of foot; enlarged.
(*g*) Parietal bones, showing foramen; enlarged.
(*h*) Vertebra; enlarged.
(*j*) Ribs; enlarged.
(*k*) Bony scale; enlarged.
(*l*) Portion of scaly cuticle.
(*m* to *s*) Horny scales, bristles, tubercles, and other appendages of the same; mag.

Fig. 144.—*Hylonomus Lyelli*, Dawson.



paper already referred to. The bones being small and of dark colour, are not very conspicuous, and many of them are broken, but many are beautifully perfect; and even those which are removed have left very distinct moulds of their form in the fine-grained matrix. In the figure I have carefully traced their outlines in their natural position, with the exception of the maxillary bone and mandible, which are removed from their place in the matrix, to bring the whole into a more compact form. The specimen also shows, in addition to the bones delineated, many fragments of the skull and scapular bones, crushed in such a manner that their forms cannot be distinguished. The specimen shows remains of thirty vertebræ, of which four appear to belong to the neck, and the rest are probably nearly all dorsal and lumbar. Of about twenty ribs more or less complete fragments remain. The fore limb is represented only by the impression of a humerus, but other bones which may have belonged to it are scattered elsewhere on the stone. The pelvis is nearly entire, though crushed and flattened. One thigh bone remains tolerably perfect, and beside it lie the tibia and a part of the fibula, with several bones of the foot. The dimensions of these parts are as follow :—

Length of	maxillary	0·7 inch.
„	mandible	0·7 „
„	longest rib (chord) . . .	0·6 „
„	humerus	0·5 „
„	femur	0·7 „
„	tibia	0·45 „
„	principal bone of pelvis . .	0·7 „

The other specimen above referred to shows the bones of the trunk, and part of those of the hind and fore limb, of a small individual, nearly in their natural position, and is remarkably instructive, as giving some idea of the general form of the trunk. It shows the humerus and radius and ulna in a tolerable state of preservation, with a fragment of the scapula. About thirteen dorsal and lumbar vertebræ can be made out, nearly in their natural position; and there are remains of five of the ribs. The hind limb is represented by fragments of the femur, tibia, and fibula.

It is evident, from the remains thus described, that we have in *Hylonomus Lyelli* an animal of lacertian form, with large and stout hind limbs, and somewhat smaller fore limbs, capable of walking and running on land; and though its vertebræ were imperfectly ossified externally, yet the outer walls were sufficiently strong, and their articulation sufficiently firm, to have enabled the creature to erect

itself on its hind limbs, or to leap. They were certainly proportionally larger and much more firmly knit than those of *Dendrerpeton*. Further, the ribs were long and much curved, and imply a respiration of a higher character than that of modern batrachians, and consequently a more highly vitalized muscular system. If to these structural points we add the somewhat rounded skull, indicating a large brain, we have before us a creature which, however puzzling in its affinities when anatomically considered, is clearly not to be ranked as low in the scale of creation as modern tailed batrachians, or even as the frogs and toads. We must add to these also, as important points of difference, the bony scales with which it was armed below, and the ornate apparatus of horny appendages with which it was clad above. These last, as described above, and illustrated in Fig. 144, show that this little animal was not a squalid, slimy dweller in mud, like *Menobranchus* and its allies, but rather a beautiful and sprightly tenant of the Coal formation thickets, vying in brilliancy, and perhaps in colouring, with the insects which it pursued and devoured. Remains of as many as eight or ten individuals have been obtained from three erect *Sigillariæ*, indicating that these creatures were quite abundant, as well as active and terrestrial in their mode of life.

With respect to the affinities of this species, I think it is abundantly manifest that it presents no close relationship with any reptile hitherto discovered in the Carboniferous system, and that it presents characters partly allying it to the newts and other batrachians, and partly to the true reptiles. The structures of the skull, and of some points in the vertebræ, certainly resemble those of batrachians; but, on the other hand, the well-developed ribs, evidently adapted to enlarge the chest in respiration, the broad pelvis, and the cutaneous covering, are unexampled in modern batrachians, and assimilate the creature to the true lizards. I have already, in my original description above quoted, expressed my belief that *Hylonomus* may have had lacertian affinities, but I do not desire to speak positively in this matter; and shall content myself with stating the following alternatives as to the probable relations of these animals:—(1.) They may have been true reptiles of low type, and with batrachian tendencies. (2.) They may have been representatives of a new family of batrachians, exhibiting in some points lacertian affinities. (3.) They may have been the young of some larger reptile, too large and vigorous to be entrapped in the pitfalls presented by the hollow Sigillaria stumps, and in its adult state losing the batrachian peculiarities apparent in the young. Whichever of these views we may adopt, the fact remains, that in the structure of this curious little creature we have peculiarities both batrachian

and lacertian, in so far as our experience of modern animals is concerned. It would, however, accord with observed facts in relation to other groups of extinct animals, that the primitive batrachians of the Coal period should embrace in their structures points in after times restricted to the true reptiles. On the other hand, it would equally accord with such facts that the first-born of lacertians should lean toward a lower type, by which they may have been preceded. My present impression is, that they may constitute a separate family or order, to which I would give the name of MICROSAURIA, and which may be regarded as allied, on the one hand, to certain of the humbler lizards, as the *Gecko* or *Agama*, and, on the other, to the tailed batrachians.

It is likely that *Hylonomus Lyelli* was less aquatic in its habits than *Dendrerpeton*. Its food consisted, apparently, of insects and similar creatures. The teeth would indicate this, and near its bones there are portions of coprolite containing remains of insects and myriapods. It probably occasionally fell a prey to *Dendrerpeton*, as bones, which may have belonged either to young individuals of this species or to its smaller congener *H. Wymani*, are found in larger coprolites, which may be referred with probability to *Dendrerpeton Acadianum*.

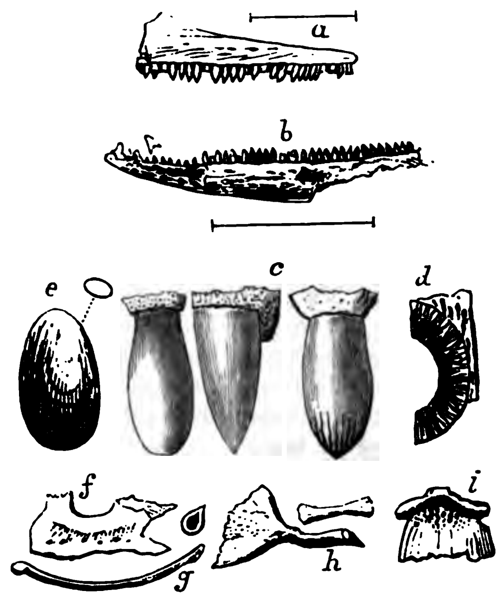
Hylonomus Aciedentatus, Dawson.

This species is founded on a single imperfect specimen obtained by me at the Joggins in 1859, and described in the Journal of the Geological Society, vol. xvi. In size, *H. aciedentatus* was about twice as large as the species last described. Its teeth are very different in form. Those on the maxillary and lower jaw are stout and short, placed in a close and even series on the inner side of a ridge or plate of bone. Viewed from the side they are of a spatulate form, and present a somewhat broad edge at top, as in Fig. 145. Viewed in the opposite direction, they are seen to be very thick in a direction transverse to that of the jaw, and are wedge-shaped. There are about forty on each side of the mandible, and about thirty on each maxillary.

Since the publication of my previous paper, I have ascertained that the intermaxillary bones bore teeth of a peculiar form. They are larger than the others, thick and coming to a blunt point, which is *seamed with longitudinal and slightly spiral ridges*. This singular tooth must have been a most efficient instrument for crushing and penetrating the coats of crustaceans and insects, or the bony armour of the smaller ganoid fishes. Remains exist at the extremity of the

lower jaw, which show that a few teeth there also were larger than the others, but whether they differed in form cannot be determined. The pulp cavity of the teeth is less extensive in proportion than in *H. Lyelli*, and the structure in the cross section is simple, showing merely radiating ivory tubes.

Fig. 145.—*Hylonomus aciedentatus*, Dawson.



(*a*) Maxillary bone; enlarged.
(*b*) Mandible; enlarged.
(*c*) Teeth; magnified, showing front and side view of ordinary tooth and grooved anterior tooth.
(*d*) Section of tooth; magnified.
(*e*) Scale; natural size and magnified.
(*f*) Pelvic bone (?); natural size.
(*g*) Rib; natural size.
(*h*) Scapular bone (?); natural size.
(*i*) Palate; natural size.

The remains of *H. aciedentatus* are too scanty to warrant much certain inference as to its form. Its vertebræ would seem to have resembled those of *H. Lyelli*, but to have been elongated and more thoroughly ossified. Its ribs are similar in form and proportion to those of the last-named species. A pelvic bone and some detached phalangial bones, as well as very fragmentary limb bones, would indicate that its limbs were well developed. Its external scales are similar to those of the last species, but larger, and a few fragments of skin show scales and appendages similar to those of *H. Lyelli*, but of greater dimensions. The microscopic structure of its bone is also

similar to that in the last species. No doubt a more perfect specimen would show many points of difference between these species, not now appreciable; but in the meantime the very different form of the teeth is a sufficient distinction. In *H. Lyelli* these are conical and pointed. In the present species they are of a peculiar wedge shape—their diameter transversely to the jaw being the greatest at the base, while at the top they are sharpened to an edge. The peculiar form of the intermaxillary teeth may also serve as a distinctive character, though those of *H. Lyelli* are not yet known. The form of the vertebræ would further seem to indicate different proportions of body. On the whole, while this species is in all probability generically related to the last, it is certainly specifically distinct. Its habits and food may have been similar, but its dental apparatus was stronger and more formidable.

Hylonomus Wymani, Dawson.

This is the species of *Hylonomus* originally detected by Professor Wyman in the specimens brought from the Joggins by Sir C. Lyell and myself. Remains of several additional individuals have since been found, but no skeleton approaching to completeness. I shall describe this, the most diminutive of the reptiles of the Nova Scotia coal, with the aid of the fragments represented in Fig. 146, most of which are almost microscopic in size.

Fig. 146.—*Hylonomus Wymani*, Dawson.

(*a*) Mandible and maxilla; nat. size.
(*b, c, d*) Portions of the same; magnified.
(*e*) Rib; nat. size and magnified.
(*f*) Bones of limb and pelvis; nat. size and mag.
(*g*) Bones of foot; enlarged.
(*h*) Scales; enlarged.
(*i*) Vertebræ; nat. size and magnified.

The skull seems to have been much of the same form as in *Hylonomus Lyelli*, but very thin and delicate, so that all the specimens hitherto found are crushed and fragmentary. The maxillary and mandibular bones are furnished with teeth which are bluntly conical in form, and in the latter bone seem to be confined to its front part, or to be very small posteriorly. They are thus much fewer in number than in the species last named. I have been able to make out only twenty-two

in the lower jaw, and they are alternately large and small, as if replaced in this manner as worn out. Their structure is of the same simple character as in the other species of *Hylonomus*, and they have large pulp cavities.

The vertebræ of this species are singular and characteristic. The bodies are elongated and hour-glass shaped, with an internal cavity of the same form filled with calc-spar, and probably once occupied by cartilage. They have, in the dorsal region at least, strong articulating and lateral processes, and were furnished with numerous delicate ribs. In one of my specimens as many as thirty-eight of these little vertebræ may be seen lying together, and many of them attached to each other. This would indicate that the body was long and slender. It was furnished with limbs similar to those of *H. Lyelli*, but of course smaller. The pelvis is of the same expanded form with that of the last species, and a pair of fore-feet lying together on one slab show the remains of four slender toes. The bones of the limbs are very delicate and thin-walled. The bony scales are oval, and similar to those of the other species of the genus, but very small.

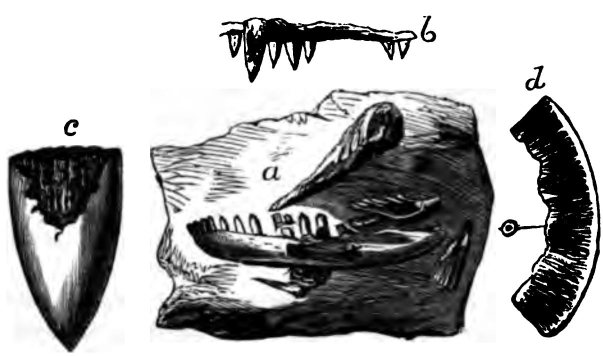
In length, *Hylonomus Wymani* could not have exceeded four or five inches, including the tail. It may indeed be questioned whether this little creature was not the young of one of the other species. The form of the vertebræ and teeth would, however, prevent us from supposing that it stood in this relation to *H. Lyelli*. To *H. aciedentatus* it bears a stronger resemblance in these respects, though not sufficient to render specific identity probable; and the occurrence of so many specimens of the smaller species, without any of intermediate size, renders it likely that it did not attain to any greater dimensions.

Hylonomus Wymani probably fed on insects and larvæ, and searched for these among the vegetable debris of the coal swamps, which would afford to a little creature like this abundant shelter. It occasionally fell a prey to its larger reptilian contemporaries; for quantities of its tiny bones occur in coprolitic masses, probably attributable to *Dendrerpeton*. It is interesting to find reptilian life represented at this early period, not only by large and formidable species, but by diminutive forms, comparable with the smallest lizards and newts of the modern world. The fact is parallel with that of the occurrence of several small mammalian species in the mesozoic beds. It will be still more significant in this respect if the species of *Hylonomus* should be found to be truly lacertian rather than batrachian.

Hylerpeton Dawsoni, Owen.

In the more or less laminated material which fills the interior of the erect trees of the Joggins, it often happens that the more distinctly separable surfaces are stained with ferruginous or coaly matter, or with fine clay, so that the fossils which occur on these surfaces, and which would otherwise be more available than those in more compact material, are rendered so obscure as readily to escape observation. This was unfortunately the case with one of the most interesting specimens contained in the last of these trees which I had an opportunity to examine. It consisted of the detached bones of a reptile scattered over a surface so blurred and stained that they escaped my notice until most of them were lost; and I was able to secure only a jaw-bone and fragments of the skull, with a few of the other bones. On these fragments Professor Owen founded the genus *Hylerpeton* and the species named at the head of this article. His description is as follows (Fig. 147):—

Fig. 147. *Hylerpeton Dawsoni*, Owen.



(*a*) Mandible and portion of cranial bone; nat. size.
(*b*) Fragment of maxilla, showing larger and smaller teeth.
(*c*) Tooth enlarged, showing pulp cavity.
(*d*) Section of tooth; magnified.

"This specimen consists of the left ramus of a lower jaw, which has been dislocated from the crushed head, of which the fore end of the left premaxillary is preserved, terminating near the middle of the series of the teeth of the more advanced mandible. A fragment of the left maxillary, which has been separated from the premaxillary, overlaps the hinder mandibular teeth. The fore part of the mandible is wanting. The teeth in the remaining part are larger and fewer, in proportion to the jawbone, than in *Hylonomus* or *Dendrerpeton*.

They have thicker and more obtusely terminated crowns; they are close-set where the series is complete at the fore part of the jaw, and their base appears to have been anchylosed to shallow depressions on the alveolar surface. The shape of what is preserved of the upper jaw affords the only evidence, and not very decisively, that the present fossil is not part of a fish. It inclines the balance, however, to the reptilian side; and, accepting such indication of the class-relations of the fossil, it must be referred to a genus of *Reptilia* distinct from those it is associated with in the Nova Scotian coal, and for which genus I would suggest the term *Hylerpeton*.

"A small part of the external surface of the dentary bone shows a longitudinally wrinkled and striate or fibrous character. The outer bony wall, broken away from the hinder half of the dentary, shows a large cavity, now occupied by a fine greyish matrix, with a smooth surface, the bony wall of which cavity has been thin and compact. We have here the mark of incomplete ossification, like that in the skeleton of *Archegosaurus*. The crushed fore part of the right dentary bone, with remains of a few teeth, is below the left dentary, and exemplifies a similar structure. The teeth slightly diminish, though more in breadth than length, towards the fore part of the series: here there are nine teeth in an alveolar extent of ten millimetres, or nearly five lines. The base of the teeth is longitudinally fissured, but the fissures do not extend upon the exserted crown. In their general characters, the teeth manifest at least as close a resemblance to those of *Ganocephala* as of *Lacertia* or any higher group of *Reptilia;* whilst their mode of implantation, with the structure and sculpturing of the bone, weigh in favour of its relations to the lower aud earlier order of the cold-blooded Vertebrates."

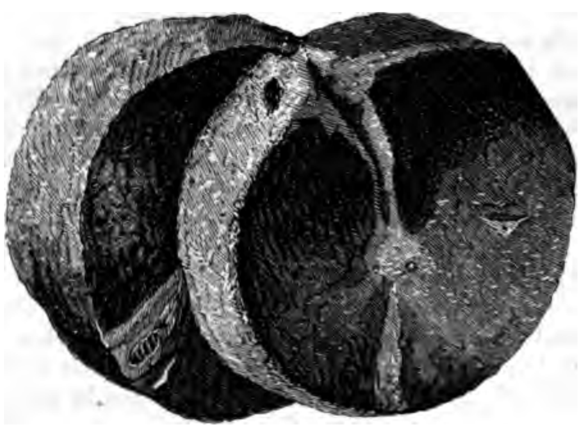
I can add to the above description only a few facts obtained from careful examination of other fragments imbedded in the matrix. One of these is a portion of a maxillary bone. It has teeth similar to those of the lower jaw in form, but the last but one is twice the size of the others, and seems to have been implanted in a deep socket. All of the teeth have large pulp cavities, and the inner surface of the ivory is marked with slight furrows which are represented by ridges on the outer surface of the stony matter filling the pulp cavities. The ivory of the teeth, however, which is very much coarser than that of the species of *Hylonomus*, presents in the cross section a simple structure of radiating tubes. The surface of the cranial bones, of which some fragments remain, is marked in the same striate manner alluded to above by Professor Owen. The microscopic structure of the bone is much coarser than that of *Hylonomus* or *Dendrerpeton*, the cells being

larger and in some portions less elongated. That the creature had stout ribs is shown by some fragments of these bones, but the vertebræ are represented only by a few bodies of small relative size and perhaps caudal. On the same surface were found the bones of a foot. It is of small size relatively to the head, and was probably for swimming rather than walking. A few ovate bony scales were found with the bones, and probably belonged to this species.

On the whole, it seems certain that *Hylerpeton* must have been generically distinct from the other reptiles found with it, and it is probable that it was of more aquatic habits, swimming rather than walking, and feeding principally on fish. More perfect specimens would, however, be required in order to warrant any decided statement on these subjects. It is possible, as suggested by Prof. Owen, that the affinities of the animal may be with *Archegosaurus* rather than with any of the other coal reptiles; but I confess that my present impression is, that it tends rather toward the genus *Hylonomus*. It may possibly be a link of connexion between the *Microsauria* and the *Archegosauria*.

Eosaurus Acadianus, Marsh.

Fig. 148.—*Eosaurus Acadianus*, Marsh. *Two vertebræ.*—Natural size.



Beside the species above described, Mr O. C. Marsh, in 1861,* added a new animal to the Joggins reptilian fauna—the *Eosaurus Acadianus*. The species is founded on two large biconcave vertebræ, in many respects resembling those of *Ichthyosaurus*, and indicating

* The remains were discovered in 1855, though not published till 1861.

a reptile of greater size than any hitherto discovered in the coal, probably of aquatic habits, and possibly allied to the great *Enaliosaurs* or sea-lizards of the mesozoic rocks. The specimen was found in a bed of shale belonging to Group XXVI. of my Joggins section, in the upper part of the Middle Coal measures, and about 800 feet above the bed which has afforded the remains described in previous sections. The beds belong to one of those intervals of shallow water deposition of sediment which separate the groups of coal beds; and on one of them I found some years ago the footprints of *Dendrerpeton*.

The vertebræ of *Eosaurus* have been fully and ably described by Mr Marsh in Silliman's Journal. Agassiz and Wyman regard their affinities as enaliosaurian. Huxley suggests the possibility, founded on his recent discovery of *Anthracosaurus Russelli*, that there may have been *Labyrinthodont* Batrachians in the Coal period with such vertebræ. However this may be, if the vertebræ were caudal, as supposed by Mr Marsh, since they are about 2½ inches in diameter, they would indicate a gigantic aquatic reptile, furnished with a powerful swimming tail, and no doubt with apparatus for the capture and destruction of its prey, comparable with that of *Ichthyosaurus*.

Pupa Vetusta, Dawson.

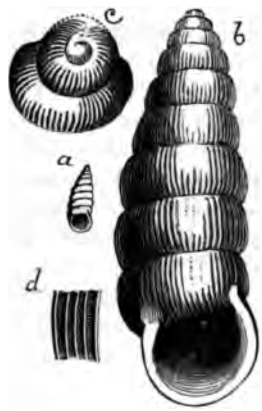
This, the first known representative of palæozoic land snails, so closely resembles the modern "chrysalis shells" of the genus *Pupa*, that I have not thought it desirable to refer it to a different genus, though the name *Dendropupa* has been proposed by Prof. Owen. Mr J. S. Jeffreys, and other eminent conchologists who have seen the shell, concur in the opinion that it is a true *Pupa*; so that this genus, and that mentioned in the next section, like *Lingula* and *Nautilus*, extend from the palæozoic period to modern times.

It may be described as a cylindrical shell, tapering to the apex, with a shining surface, marked with longitudinal rounded ridges. The whorls are eight or nine, rounded, and the width of each whorl is about half the diameter of the shell. The aperture is rather longer than broad; but is usually somewhat distorted by pressure. The margin of the lip is somewhat regularly rounded, and is reflected outward. There are no teeth, but a slight indication of a ridge or ridges on the pillar lip, which may, however, be accidental. Length 3-10ths of an inch, or a little more. It was first recognised by Dr Gould of Boston, in specimens obtained by Sir C. Lyell and the writer in 1851, in an erect Sigillaria, containing bones of reptiles, at the Joggins.

This little shell is remarkable, not merely for its great antiquity, but also because it is separated by so wide an interval of time from

other known species of its race, there being, with the exception of the next species, no other Pulmonate known until we reach the Purbeck beds, and no other true land snail until we reach the Tertiary.

Fig. 149.—*Pupa Vetusta*, Dawson.



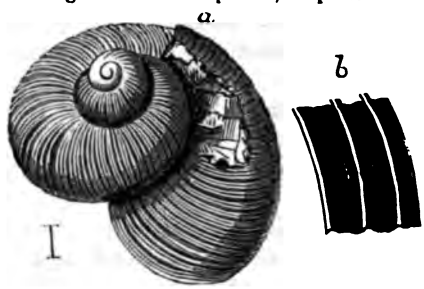
(*a*) Natural size. (*b*) Enlarged. (*c*) Apex enlarged. (*d*) Sculpture; magnified.

In the section of the South Joggins I have noticed the occurrence of *Pupa Vetusta* in another bed 1217 feet below that above mentioned. It belongs to group 8 of the section, and is between coals 37 and 38 of Logan's sectional list. It is a layer of gray indurated clay, with a slightly nodular structure, and in some places becoming black and carbonaceous, and containing leaflets of ferns, *Trigonocarpa*, etc. The shells occur very abundantly in a thickness of about two inches. They have been imbedded entire; but most of them have been crushed and flattened by pressure. They occur in all stages of growth; the young being, as is always the case in such shells, very different in general form from the adults. This bed is evidently a layer of mud deposited in a pond or creek, or at the mouth of a small stream in shallow water. In modern swamps multitudes of shells occur in such places; and it is remarkable that in this case land shells should alone be found, without any trace of aquatic molluscs. The shells which occur in this bed are filled with the surrounding sediment. Those which occur in the erect *Sigillariæ*, on the other hand, except when they are crushed and flattened, are filled with a deposit of brown calc-spar. I infer from this that the latter, when buried, contained the animals, and consequently that these lived or sheltered themselves in the hollow trees, as is the habit of many modern land snails.

Zonites (*Conulus*) *priscus*, Carpenter.

In the summer of 1866 I made some excavations in the bed above mentioned, and disinterred great numbers of the shells of the *Pupa*. My object was to find other remains if possible; and I was rewarded with the discovery of another little land shell, which my friend Dr P. P. Carpenter has described under the above name (Fig. 150).* It

Fig. 150.—*Conulus priscus*, Carpenter.

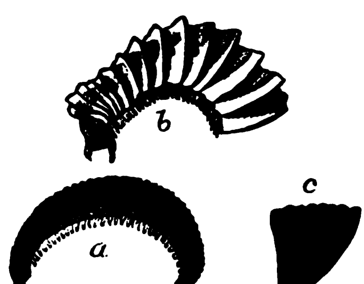


(*a*) Specimen; enlarged 12 diameters. (*b*) Sculpture; magnified.

is quite different from the *Pupa*, being snail-like in form, with a wide aperture and a very thin shell, sculptured on the surface in a different way. The sub-genus *Conulus* is a subdivision of the old genus *Helix*, and is a group of modern snails, sometimes included in the genus *Zonites*. I may add that in the collections made in 1866 there are fragments which may indicate the existence of at least one other land snail, but not sufficient for description.

Xylobius Sigillariæ, Dawson.

Fig. 151.—*Xylobius Sigillariæ*, Dawson.



(*a*) Natural size. (*b*) Anterior portion; enlarged. (*c*) Posterior portion; enlarged.

I proposed, in 1859, the above name for an articulated worm-like animal, of which numerous flattened specimens were found associated

* Journal of Geological Society, Nov. 1867.

with the *Pupa vetusta*. I was at first disposed to regard it as the larva of a coleopterous insect; but a careful microscopic examination of the specimens convinced me that it is a chilognathous Myriapod, allied to *Iulus*. It may be described as follows (Fig. 151):—

Body crustaceous, elongate, articulate; when recent, cylindrical, or nearly so, rolling spirally. Feet small, numerous; segments 30 or more; anterior segments smooth, posterior with transverse wrinkles, giving a furrowed appearance. In some specimens traces of a series of lateral pores or stigmata. Labrum (?) quadrilateral, divided by notches or joints into three portions. Mandibles two-jointed, last joint ovate and pointed. Eyes, ten or more on each side.

This animal, the oldest gally-worm known at the time of its discovery, must, like its modern congeners, have haunted the decaying trunks of swamps, and thus became entombed in the hollow *Sigillaria* in which it was found. Since its discovery, animals of similar type have been recognised in the Coal formations both of Great Britain and of the United States.

Haplophlebium Barnesii, Scudder.

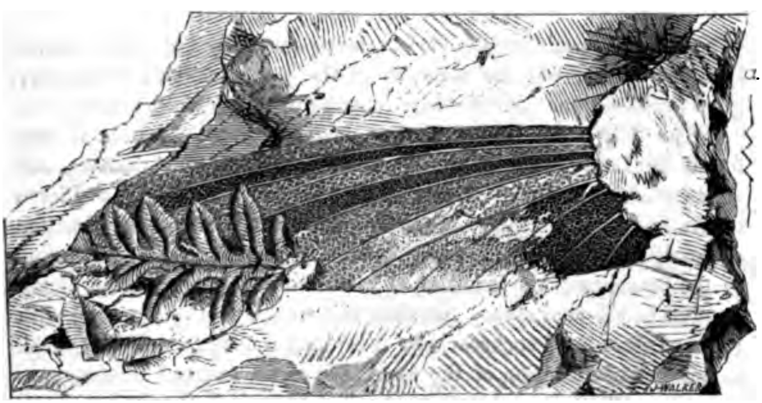
The existence of insects in the Carboniferous period has long been known. The Coal formations of England and of Westphalia afforded the earliest specimens; and, more recently, some interesting species have been found in the Western States.* They belong to the order of the *Neuroptera* (shad-flies, etc.), the *Orthoptera* (grasshoppers, crickets, etc.), and *Coleoptera* (beetles, etc.)

In the Coal-field of Nova Scotia, notwithstanding its great richness in fossil remains of plants, insects had not occurred up to last year, except in a single instance—the head and some other fragments of a large insect, probably neuropterous, found by me in the coprolite or fossil excrement of a reptile enclosed in the trunk of an erect *Sigillaria* at the Joggins, along with other animal remains. This specimen was interesting chiefly as proving that the small reptiles of the Coal period were insectivorous, and it was noticed in this connexion in my "Air-breathers of the Coal period." Last year, however, Mr James Barnes, of Halifax, was so fortunate as to find the beautiful wing represented in Fig 152, in a bed of shale at Little Glace Bay, Cape Breton. The engraving is taken from a photograph kindly sent to me by Rev. D. Honeyman, F.G.S. It will be observed that, in consequence probably of the mutual attraction of loose objects floating about in water, a fragment of a frond of a fern, *Alethopteris lonchitica*, lies partly over the wing, obscuring its outline, but bearing testimony to its carbon-

* See Lyell's "Elements," and Dana's "Manual" for references.

iferous date. The wing has been examined by Mr S. H. Scudder, of Boston, who has made such specimens his special study, and who refers it to the group of Ephemerina (day-flies, shad-flies) among the Neuroptera, and has named it *Haplophlebium Barnesii.* It must have been a very large insect—seven inches in expanse of wing—and therefore much exceeding any living species of its group. When we consider that the larvæ of such creatures inhabit the water, and delight in muddy bottoms rich in vegetable matter, we can easily understand that the swamps and creeks of carboniferous Acadia, with its probably mild and equable climate, must have been especially favourable to such creatures, and we can imagine the larvæ of these gigantic ephemeras swarming in the deep black mud of the ponds in these swamps, and furnishing a great part of the food of the fishes inhabiting them, while the perfect insects emerging from the waters to enjoy their brief span of aërial life, would flit in millions over the quiet waters and through the dense thickets of the coal swamps.

Fig. 152.—*Haplophlebium Barnesii*, Scudder.



(*a*) Profile of base of wing.

Mr Scudder describes the species as follows:—

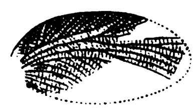
"This is probably one of the *Ephemerina*, though it differs very much from any with which I am acquainted. The neuration is exceedingly simple, and the intercostal spaces appear to be completely filled with minute reticulations without any cross-veins. The narrowness of the wing is very peculiar for an *Ephemeron.* The form of the wing and its reticulation remind me of the *Odonata*, but the mode of venation is very different; yet there is apparently a cross-vein between the first and second veins in the photograph (not rendered in the cut) which,

extending down to the third vein, occurs just where the "nodus" is found in *Odonata*, and if present would unquestionably remove this insect to a new synthetic family between *Odonata* and *Ephemerina*. I cannot judge satisfactorily whether it is an upper or an under wing. The insect measured fully seven inches in expanse of wings—much larger than any living species of *Ephemerina*.

Archimulacris Acadicus.

The new genus and species above named (Fig. 153), have been founded by Mr Scudder on a beautiful little wing discovered by Mr Barnes at the East River of Pictou, in shale overlying the main seam

Fig. 153.—*Archimulacris Acadicus.*



of coal. The specimen is imperfect, being cut off by a leaf of Cordaites lying across it; but the venation of the part remaining is in very good preservation. Mr Scudder remarks upon it as follows:—

"The only fossil cockroach yet described from America is that found by Lesquereux in the Carboniferous beds of Arkansas, and called *Blattina venusta*. The wing discovered by Mr Barnes at Pictou differs from it in the curve of the costal border (affecting the direction of nearly every vein in the wing), as well as in the extent and direction of the branches of the mediastinal vein, and in the distribution of the veinlets in the anal area. Nor does this wing agree in character with those of other fossil cockroaches; it is allied to some which Dr Giebel, in his generic division of the fossil *Blattariæ*, referred to the genus *Blattina*. With two exceptions, he had placed all the Carboniferous cockroaches in the same group. This species, forming the type of a new genus, may be called *Archimulacris Acadicus*. The generic term is derived from the Greek name of a cockroach."

In the Journal of the Geological Society, 1861, I described as follows some very remarkable impressions found on the surface of a rain-marked sandstone at the Joggins, containing also reptilian footprints:—"They consist of rows of transverse depressions, about an inch in length and one-fourth of an inch in breadth. Each trail consists of two of these rows running parallel to each other, and about

six inches apart. Their direction curves abruptly, and they sometimes cross each other. From their position they were probably produced by a land or fresh-water animal—possibly a large Crustacean or or gigantic Annelide or Myriapod. In size and general appearance they slightly resemble the curious *Climactichnites* of Sir W. E. Logan, from the Potsdam sandstone of Canada." To this I may add that the space between the rows of marks is slightly depressed and smoothed, as if with a heavy body like that of a serpent trailed along. The recent remarkable discovery in the Coal-field of Kilkenny, Ireland, of the large serpentiform Batrachian, described by Huxley under the name *Ophiderpeton*, leads to the supposition that these trails may indicate the existence of a similar creature in Nova Scotia.

The contents of this chapter may be summed up in the statement, that the Coal formation of Nova Scotia has afforded of terrestrial Vertebrates no less than eight species of reptiles, some of them probably of higher type than the Batrachians; of land Mollusks the only two species known in the Palæozoic rocks; of land Articulates one millipede and two insects. While the reptiles differ much from existing types, and belong to families which have long ago passed away, the mollusks and articulates are remarkably like the creatures of their rank found in similar places at the present time, belonging in two instances even to the same generic groups.

Note.—While this chapter is passing through the press, I am informed by Mr Scudder, to whom I have submitted the numerous fragments of Myriapods in my collection from the Joggins, that he thinks he can recognise three additional species of *Xylobius* and a new generic form (*Archiulus*). I hope to give descriptions of these in the Appendix.

CHAPTER XIX.

THE CARBONIFEROUS SYSTEM—*Continued.*

CARBONIFEROUS DISTRICT OF RICHMOND AND SOUTHERN INVERNESS—USEFUL MINERALS—DISTRICT OF NORTHERN INVERNESS AND VICTORIA—USEFUL MINERALS—DISTRICT OF CAPE BRETON COUNTY—USEFUL MINERALS.

Carboniferous District of Richmond and Southern Inverness.

THIS district is separated from those of Sydney and Guysboro' only by the Strait of Canseau, a narrow transverse valley excavated by the currents of the drift period. The Lower Carboniferous conglomerates and limestones are seen on both sides of the strait, and the lowest members of the system are seen at Plaister Cove and its vicinity, and are succeeded to the southward and eastward by the Coal formation. As this district presents some curious and interesting features, I shall notice some parts of it in detail.

The coast section in the vicinity of Plaister Cove is remarkable for the highly perfect manner in which it displays the gypsiferous rocks, and the information which it consequently affords as to their structure and origin.

The following summary of the beds seen in this section is from a paper contributed by the writer to the Geological Society in 1849 (see Fig. 154):—

"(1.) At M'Millan's Point, about three-quarters of a mile north of the Cove, are thick beds of gray conglomerate, in a vertical position. These beds form the base of the Carboniferous system in this district; and, at a short distance inland, they have been invaded by trap and other igneous rocks, belonging to a great line of igneous disturbance extending to the north-eastward. The conglomerates near M'Millan's Point have been thrown up along an anticlinal line connecting the igneous range last mentioned with that of Cape Porcupine, on whose flanks the same conglomerates appear. The valley now occupied by the strait is in great part due to the want of continuity of the igneous masses at this point, though the distribution of the surface detritus

shows that it has been subsequently deepened by diluvial waves or currents from the northward.

Fig. 154.

Coast Section at Plaister Cove.

1. Hard gray conglomerate. 2. Alternations of hard sandstone and gray shale. 3. Limestone. 4. Marl. 5. Gypsum. 6. Gypseous limestone. 7. Marl. 8. Dark shales with calcareous bands. 9. Brown and gray sandstone and shale.

"(2.) Between M'Millan's Point and Plaister Cove the shore is occupied by black and gray shales and very hard sandstones in frequent alternations. The sandstones have been much altered by heat, and are traversed by veins of white carbonate of lime, sometimes mixed with sulphate of barytes. At the point immediately north of Plaister Cove these beds dip at a high angle to the south-eastward.

"(3.) Overlying these beds is a bed of limestone about thirty feet in thickness; it is of a dark colour, laminated and subcrystalline; its laminæ are in some parts corrugated and slightly attached to each other, and in other places flat and firmly coherent; it is traversed by numerous strings of white calcareous spar, containing a little carbonate of iron and small crystals of blue fluor-spar, a mineral rare in Nova Scotia, and which I have found only in the Lower Carboniferous limestones. The limestone supports a few layers of greenish marl

and gypsum, which appear in a small depression on the north side of the Cove; but beyond this depression the limestone reappears with a northerly dip. It is then bent into several small folds, and ultimately resumes its high dip to the south-east. I found no fossils in this limestone, except at its junction with the overlying marl, where there is a thin bed of black compact limestone containing a few indistinct specimens of a small species of *Terebratula*. In appearance and structure this limestone is very similar to the laminated limestones which underlie the gypsiferous deposits of Antigonish and the Shubenacadie.

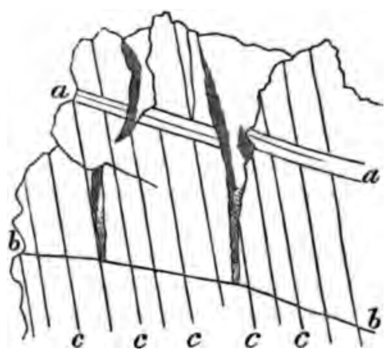
"(4.) This bed is succeeded by greenish marl, traversed by veins of red foliated and white fibrous gypsum, and containing a few layers of the same mineral in a granular form; it also contains a few veins of crystalline carbonate of lime. In its lower part it has a brecciated structure, as if the layers had been partially consolidated and afterwards broken up. Near its junction with the limestone it contains rounded masses of a peculiar cellular limestone, coloured black by coaly matter; and higher in the bed there are nodules of yellow ferruginous limestone, with a few fragments of shells. The greenish colour of the marl seems to be caused by the presence of a minute quantity of sulphuret of iron. When a portion of the marl is heated the sulphuret is decomposed, and the colour is changed to a bright red.

"(5.) On this marl rests a bed of gypsum, whose thickness I estimated at fifty yards. Where the marl succeeds to the limestone, the shore at once recedes, and the gypsum occurs at the head of the Cove. The gypsum is well exposed in a cliff about eighty feet in height; but, like most other large masses of this rock, it is broken by weathering into forms so irregular that its true dip and direction are not at first sight very obvious. On tracing its layers, however, it is found to have the same dip with the subjacent limestone and marl. About two-thirds of the thickness of the bed consist of crystalline anhydrite, and the remaining third of very fine-grained common gypsum. The anhydrite prevails in the lower part of the bed, and common gypsum in the upper; but the greater part of the bed consists of an intimate mixture of both substances, the common gypsum forming a base in which minute crystals of anhydrite are scattered; and bands in which anhydrite prevails, alternating with others in which common gypsum predominates. It is traversed by veins of compact gypsum, but I saw no red or fibrous veins like those of the marl. In some parts of the bed small rounded fragments of gray limestone are sparingly scattered along layers of the gypsum.

"The exposed part of the mass is riddled by those singular funnel-

shaped holes named "plaster pits," sections of which are exposed in the cliff; they penetrate both the anhydrite and common gypsum, though they are contracted where they pass through harder portions of the rock, and especially the veins of compact gypsum, some of which are only slightly inclined, and look at first sight like layers of deposition. The pits of which I saw sections have evidently resulted from the percolation of water through the more open parts of vertical joints, and they were cut off where they were intersected by another slightly inclined set of open fissures, which afforded a passage to the water. The accompanying sketch (Fig. 155) shows one of these pits and its relations to the joints and stratification of the gypsum.

Fig. 155.—*Plaster Pits.*



(*a*) Gypsum vein. (*b*) Open joint. (*c*) Bedding of the gypsum.

"(6.) Above the gypsum are a few layers of limestone, portions of which appear near the base of the cliff: one of them is studded with tarnished crystals of iron pyrites; another is a singular mixture of gray limestone and reddish granular gypsum. The portions of limestone contained in this rock do not appear to be fragments or pebbles, and they are penetrated by plates of selenitic gypsum. They may be parts of a bed of limestone broken up and mixed with gypsum when in a soft state, or the limestone and gypsum may have been deposited simultaneously and separated by molecular attraction. A rock of this kind is not rare as an accompaniment of gypsum, and it may be merely a result of the mixture of the soft surface of the gypsum with the mechanical detritus first deposited on it.

"(7.) On the opposite side of the creek, which makes a small break in the section, is a thick bed of marl, whose dip appears to be the same with that of the gypsum. In general character it resembles the

marl underlying the gypsum. In some parts it is greenish and homogeneous in texture; in other parts it is brecciated, and some layers have a brownish colour and shaly texture. In some parts it is highly gypseous and contains layers of granular gypsum, one of which is black, its colour being due to a small proportion of coaly or bituminous matter.

"(8.) Beyond the marl the shore is occupied for a short space by boulder clay. Beyond this it shows a great thickness of dark shales with calcareous bands, containing a few small shells belonging to the curious little crustacean, *Leaia Leydii*, represented in Fig. 78 *e* above. They dip to the E.S.E. at a high angle, and overlie the gypsum. They are succeeded by a thick band of very hard gray and brownish sandstones and shales, containing a few fragments of plants stained with carbonate of copper. These are again overlaid by dark shales, and these by an enormous thickness of gray and brown sandstone and shale. Some of the shales in this part of the section have assumed a kind of slaty or rather prismatic structure."

I beg the reader to observe, in the above section, the contrast between the hardened sandstones and shales and the soft marls and gypsum, a contrast equally marked in other parts of the Carboniferous districts, and often producing, by the removal of the softer beds, that isolated position of the gypsum masses which is frequently so perplexing. It is also important to observe, that this great mass of gypsum is a regular bed, interstratified with the others, and belonging to the series of processes by which the whole were formed. I have already, in noticing the gypsum of Windsor, referred to its probable origin, and may now apply the same method of explanation to that of Plaister Cove. On this view, then, the history of this deposit will be as follows:—

First, The accumulation of a vast number of very thin layers of limestone, either so rapidly or at so great a depth that organic remains were not included in any except the latest layers. *Secondly*, The introduction of sulphuric acid, either in aqueous solution or in the form of vapour; the acid being a product of the volcanic action whose evidences remain in the neighbouring hills. At first the quantity of acid was too small, or the breadth of sea through which it was diffused too great, to prevent the deposition of much carbonate of lime along with the gypsum produced; and its introduction was accompanied by the accumulation on the sea-bottom of a greater quantity of mechanical detritus than formerly: hence the first consequence of the change was the deposition of gypseous marl. At this stage organic matter was present, either in the sea or the detritus deposited, in

sufficient quantity to decompose part of the sulphate of lime, and produce sulphuret of iron; and also to afford the colouring matter of the nodules of black limestone found in the marl. *Thirdly*, The prevalence for a considerable period of acid waters, combining with nearly all the calcareous matter presented to them, and without interruption from mechanical detritus. The anhydrite must have been deposited with the common gypsum; but, under the circumstances, it seems difficult to account for its production, unless it may have been formed by acid vapours, and subsequently scattered over the bed of the sea. *Fourthly*, A return to the deposition of marl, under circumstances very similar to those which previously prevailed; and, *lastly*, The restoration of the ordinary arenaceous and argillaceous depositions of the Carboniferous seas.

Of the gypsum veins found in the marls, those which are white and fibrous may have been nearly contemporaneous in their origin with the marl itself; those which are red and lamellar have been subsequently introduced. The granular gypsum is in all cases a part of the original deposit. The comparatively small quantity of red oxide of iron in these marls and other associated beds is the most important feature of difference between the deposit of Plaister Cove and those of most other parts of this province. There is, however, a large quantity of reddish and brown sandstone in the beds overlying the gypsum, though on the whole these colours are less prevalent than in the Carboniferous system of Nova Scotia proper.

The rocks seen at Plaister Cove and its vicinity appear to be overlaid in ascending order by a great thickness of black shales, which, near Ship Harbour, contain shells of *Naiadites*. These shales are succeeded by true Coal measures, which, at Little River and at Carribou Cove, contain seams of coal and a variety of characteristic fossil plants. One remarkable peculiarity of these Coal measures is, that they have been folded up by lateral pressure, so that they are often vertical, and that the limestones with marine shells and the gypsum, are often brought into immediate contact with masses of these disturbed Coal measures. Coal measure beds in a less disturbed condition extend up the River Inhabitants nearly to its sources, and occupy the country between that river and the southern part of the Bras d'Or Lake. The Lower Carboniferous limestone appears on the north-west arm of River Inhabitants, at West Bay, at Lennox Passage, on Isle Madame, and at St Peter's. At Lennox Passage it is associated with a great bed of excellent gypsum, and contains an abundance of fossil shells. At St Peter's it is non-fossiliferous, and rests against syenite and metamorphic slates, forming the western margin of a large tract

of metamorphic country, along the edge of which it extends, with some conglomerate and sandstone, in a very narrow belt, skirting the whole eastern side of the Bras d'Or Lake, and connecting this district with that of the county of Cape Breton.

Useful Minerals of the District of Richmond, etc.

Coal appears at various places in this district, and at the time when my first edition was printed, it was the only place in which any exploration had been made by the Government. In consequence of a petition from the inhabitants, the Legislature voted a small sum for a reconnaissance of this district. I had the honour to be employed in this work, and this was the only geological work for which I ever received any payment from the Government of Nova Scotia. I mention this circumstance, because it accounts for the fact that so much space is given to this coal-field in my first edition, while the far more important mines of Cape Breton County, which I had not the same opportunity to examine, are treated of more slightly.

Coal.—The bed at Carribou Cove, or Sea Coal Bay, has attracted some attention, owing to its appearance in the coast section in a very accessible situation. It is a seam of mixed coal and bituminous shale eleven feet eight inches in thickness, in a vertical position, or rather thrown over on its face; its dip being W. 57° S., at an angle of 80°, and the bed which was originally its underclay being its roof. The coal from the outcrop of this bed is of a soft and crumbling quality, and filled with layers of shale.

A specimen of the best coal, selected from different parts of the bed, gave, on analysis,—

Volatile matter	25·2
Fixed carbon	44·7
Ash	30·1
	100·

The shale associated with the coal contains a sufficient quantity of bituminous and coaly matter to render it combustible, but it differs from coal in leaving a stony residue instead of a pulverulent ash.

It appears from the above analysis that the best coal of this bed is very impure, its percentage of ash being double that of Pictou coal; and when this is taken in connexion with its intimate intermixture with shale, it must be evident that the produce of this seam could scarcely be exported with profit. It might possibly be worked to

supply fuel of an inferior description for use in the neighbouring country. In the deeper parts of the bed, the coal is probably harder and of much better appearance than at the outcrop, but in its mixture with shale and high percentage of ash no material improvement can be expected. It will also be found to contain a large proportion of the bi-sulphuret of iron, much of which has been removed from the outcrop by weathering.

The other strata seen in the vicinity of the coal are gray shales and hard sandstones, with a small seam of bituminous shale. No other bed of coal appears in the vicinity, though, as the coast section for about half a mile on either side shows little except boulder-clay, it cannot be affirmed that others are not present. If other beds occur, they can be found only by expensive works of discovery, unless accidentally uncovered by excavations made for other purposes. Since the above description was written, these beds have been farther explored, and a bed of coal four feet thick is stated to have been found, but the working of this bed has not been prosecuted.*

Coal also appears at Little River, a small stream emptying a little to the eastward of Carribou Cove. At the mouth of this stream there is a bed of gypsum. The coal occurs two and a half miles inland. Here, as at Carribou Cove, the measures are vertical, the strike or direction of the beds being N. 40° W. Two beds are seen at this place, one four feet in thickness, the other ten inches thick. They are separated by five feet of shale. Above the place where they cross the river I observed in the bed of the stream fragments of coal and bituminous shale, which have probably been washed from the outcrop of a third bed.

The coal of the principal bed is hard, and very little injured by exposure. Its fracture is uneven and crystalline, with glistening surfaces; and its texture is very uniform, the lamination or "reed" being rather indistinct, and almost free from dull coal or mineral charcoal. Its specific gravity is 1·38. When burned in a stove or grate, it ignites readily, fuses, swells, and cakes, giving a strong flame and a lasting fire. It leaves a rather large quantity of brownish ash. In a smith's forge it works well, its behaviour being similar to that of Pictou coal. On analysis, it is found to contain,—

Volatile matter . .	30·25
Fixed carbon . . .	56·40
Ash	13·35
	100·

* Rutherford's Report.

Compared with the coals of Pictou and Sydney, the Little River coal is more bituminous than either, or contains more volatile matter and less fixed carbon. It contains about the same quantity of earthy matter with Pictou coal; but in quality and colour the ash resembles that of Sydney. Practically it will be found to be a serviceable coal for domestic fires, well adapted for smiths' use, and, from the large quantity and high illuminating power of its gaseous matter, probably a good gas-coal. There should be little waste in its extraction, and it will suffer little by being "banked" or kept in the open air. It contains more sulphur than the Pictou coal.

The coal of the small bed (No. 2) is somewhat similar to that of No. 1; but it is more impure, and contains much bi-sulphuret of iron. The fragments found in the river, and supposed to be derived from a third bed, are very similar to the coal of No. 2.

The point at which the coal appears on Little River is distant in a direct line from the main road to Ship Harbour about one mile and a half, and from Ship Harbour four miles; from the shore at Carribou Cove two miles and a half; and from the navigable part of River Inhabitants two miles and a quarter. In the direction of the Strait of Canseau, the Coal measures appear to be cut off at the distance of about half a mile from the river, by one of the fractures which abound in the district. In the opposite direction, it is possible that they may extend to the estuary of the River Inhabitants.

In the direction of the beds of coal, the ground in the vicinity of the river is low, rising to about thirty feet only above the stream. Only a very small depth of coal could therefore be drained by a level from the river-bed, or without the aid of machinery. The vertical position of the beds will also require a method of mining different from that employed in the other coal-fields of the province, where the seams are only slightly inclined. These circumstances, in addition to the comparatively small dimensions of the beds, as they tend to increase the expense of extracting coal, must operate as objections to the opening of this deposit. On the other hand, the seam No. 1 is sufficiently large to be conveniently worked, its coal would command a fair price in the market, and it is near harbours from which its produce could be shipped at any season. There is also a probability that the beds might be traced to localities more favourable for the extraction of the coal; and that, by works of discovery carried on in the adjacent measures, other workable seams might be found. I am glad to learn that, since the above remarks were written in my first edition, this mine has been opened, and is known as the "Richmond Mine." A second bed of coal, 154 feet distant from the first, has been

discovered. The mine is worked on the long-wall system, somewhat in the manner of a mineral vein. A railway has been formed to the shore; and in 1866, 1016 tons of coal were extracted.

Coal also appears at the basin of Inhabitants, and in two places on the river of the same name; but I am not aware whether it is of any practical importance. I would suggest, however, to explorers the valley of the River Inhabitants as a promising field of investigation.

The only other useful minerals found in the district are limestone and gypsum. The most accessible deposit of the former is that of Plaister Cove, which is large and of fair quality. Large beds of good limestone also occur at Little River and the north-west arm of River Inhabitants. The bed of gypsum from which Plaister Cove derives its name is of enormous thickness, and contains some good gypsum, though about two-thirds of its thickness consist of anhydrous gypsum or "hard plaster." The bed which occurs near Carribou Cove is of good quality; but where it appears on the shore it is deeply covered with boulder-clay. A little farther inland, however, it is nearer the surface. The marls associated with these beds, as they contain large quantities of carbonate and sulphate of lime in a finely divided state, might be usefully applied as a dressing to land.

Gypsum has been exported from the bed already mentioned at Little River, and to a considerable extent from Lennox Passage, where, as well as at Arichat and St Peter's, there is good limestone.

Carboniferous District of Northern Inverness and Victoria.

In following the coast sections to the northward and westward of Plaister Cove, we find the Carboniferous rocks reduced to a narrow belt, by the projection of a mass of igneous and altered rocks toward the coast. The conglomerate appears in several places, and also the Lower Carboniferous limestone, which has been altered into a variegated marble, capable of heing applied to ornamental purposes. At Long Point the metamorphic hills begin to recede from the coast, and from Port Hood the Carboniferous rocks extend quite across the island to St Ann's Harbour, and northward to Margarie, beyond which place a narrow belt continues to line the coast as far as Cheticamp.

At Port Hood, the Coal measures appear with characters very similar to those of the Joggins section. Their dip is W. 20°, in some places varying to W. by N. 25°; so that their strike nearly coincides with that of the shore, and only a small thickness of beds can be seen in the coast section. The beds seen consist of gray sandstones and gray and brown shales, with black and calcareous shales, and thin seams of coal. *Calamites*, *Sternbergia*, *Stigmaria*, and coniferous wood abound;

and, in a bed of sandstone a little to the northward of the village, magnificent examples of Sigillaria stumps, with their roots and rootlets attached, are seen *in situ*. The beds dipping seaward at a small angle, and undergoing rapid waste, expose these stumps on a horizontal surface, and not in a vertical cliff as at the Joggins; and this affords great facilities for studying the arrangement of their singular roots. Some of the stumps are two feet and a half in diameter, and may be seen to give off their pitted Stigmaria roots in four main divisions, exactly at right angles to each other, each main root subdividing regularly into two, four, and so on. They are in the state of casts in hard calcareous sandstone, and they have grown on a soil consisting of loose sand, now sandstone, and stiff clay, now represented by beds of shale. Some of the layers of sandstone immediately under the roots are distinctly ripple-marked, and must, when the trees grew on them, have been either very recently elevated from the sea-bed, or must have been layers of blown sand. If it were not for the general uniform bedding of the Coal formation sandstones embedding these plants, an observer would be strongly inclined to refer them to the latter cause; and I think it by no means impossible that some of them may have had such an origin, and may have been afterwards smoothed and levelled by water, before the overlying beds were deposited on them.

More than one generation of these trees have grown on this spot, for I observed one of the stony trees to be penetrated by a cast of a Stigmaria with rootlets attached, which passed quite through it. This had manifestly belonged to a new generation of trees, growing above the remains of others already in the state of casts in sand, but not consolidated into stone.

One of the beds of shale in the vicinity of a small coal seam at this place, contains abundance of *Naiadites*, *Cythere*, fish-scales and teeth, and *Coprolites*, or the fossil excrement of fishes. A fragment of a large *Eurypterus*, previously figured (Fig. 50) was also found here.

Four miles to the north-east of Port Hood, the Lower Carboniferous limestone and gypsum appear; and this part of the system continues to Mabou River, where it is very extensively developed. The limestone near this river has shells of *Productus semireticulatus* and abundance of fragments of *Encrinites;* and one of the beds has an *Oolitic* structure,—that is, it is made up of small round grains, precisely like small shot cemented together, or the roe of a fish. This peculiar structure is supposed to have been produced by the calcareous matter collecting itself around minute grains of sand or other bodies, and thus taking the form of little concretionary balls, which were finally cemented into rock. It was at one time supposed to be confined to a

particular part of the geological series, still named in England the Oolitic formation, but it has been found in rocks of very different ages. Examples of it occur in the limestones of Windsor and Pictou; but this of Mabou is much more perfect. Its little rounded grains are nearly quite uniform in size, smooth and black, and cemented together by gray calcareous matter.

Near the mouth of Mabou River there is an enormous bed of gypsum, which was being quarried when I last visited it for the purpose of making road-embankments, this rock being the only available material at hand. Enormous plaster-pits have been excavated in the outcrop of this great gypseous mass. One of them forms a circular grassy amphitheatre, capable of containing hundreds of persons, and I was informed that there is a spring of water in its centre.

Immediately to the northward of Mabou River the lower conglomerates crop out from under the limestones and gypsum, and rise on the flanks of Cape Mabou, a lofty headland, the nucleus of which is syenite, of greater antiquity than the Carboniferous system, and which is connected with an isolated chain of igneous and metamorphic hills extending for some distance to the northward.

At Margarie, the Coal formation again appears, with its characteristic fossil plants; but it occupies only a very limited area, and the whole of the remainder of this district seems to consist of beds of the Lower Carboniferous series. Mr Poole, of Glace Bay, informs me that he has received from Margarie specimens of coal somewhat resembling cannel, and affording 41·10 per cent. of volatile combustible matter; but I have no information as to its quantity, or whether it was obtained from the Coal formation or the Lower Carboniferons series. The Coal formation rocks of Port Hood and Margarie are evidently only the margin of a coal-field extending under the sea, and perhaps as far as its appearance above the sea-level is concerned, in great part swept away by the waves. This coast is now rapidly wasting, in consequence of its exposure to the prevailing westerly winds blowing across the whole width of the Gulf of St Lawrence; and its rivers and harbours are from this cause choked with shifting sands. Owing to this waste of the coast, a sand-beach which connected Port Hood Island with the mainland has been swept away, and a safe harbour has thus been converted into an open roadstead, exposed to the northerly winds and encumbered with shoals. This will prove a serious drawback to any attempt to work the coal-beds of this locality.

The Lower Carboniferous limestone and gypsum appear at Cheticamp, in a number of places on Margarie River, and at Ainslie Lake, which is a fine sheet of water, more than ten miles in length, and the

largest lake, properly so called, in Cape Breton. To the eastward of this lake, a spur from the metamorphic country to the northward separates this part of the district from the Lower Carboniferous country of the county of Victoria. At the extremity of this spur, on the border of Whykokomagh Basin, the Lower Carboniferous conglomerate with syenitic pebbles forms a hill named the Salt Mountain. On this conglomerate rest thick beds of laminated limestone, from which rise unusually copious springs, some of them of pure water, others said to be salt or brackish. At Middle River, we again find the Lower Carboniferous limestone with several of its characteristic fossil shells; and from this place, as far as St Ann's Harbour and the Big Bras d'Or, the whole of the low country consists of sandstone, shale, and conglomerate, with limestone and gypsum appearing in several places. A lofty ridge of syenitic rocks separates St Ann's from the Bras d'Or, and at its extremity, Cape Dauphin, there is a patch of Carboniferous rocks which have been described in detail by Mr Brown in the Proceedings of the Geological Society. Mr Brown gives the following section, which is interesting as illustrating the arrangement of the several members of the series in this part of Cape Breton. The order is descending, and the beds dip S. 80° E. at an angle of 58°.

Lower Coal measures, seen about half a mile from Cape Dauphin—a few fossil plants—thickness not stated.	
Fine grained and pebbly sandstones (millstone-grit)—fossil plants	200 ft.
Finely laminated gray shales with thin bands of limestone	110
Slaty sandstones with traces of plants	10
Blue and gray shales with thin beds of nodular limestone	120
Strong sparry limestone	6
Soft crumbling marls	90
Strong limestone	18
Brown sandstone	12
Red shales	33
Blue shales	8
Strong limestone—lower beds laminated—fossil shells *Productus cora*, *Encrinus*	17
Mottled red and green marls	24
Intermingled sandstones and limestone	22
Blue shale	6
Red shale	8
Carry forward	684 ft.

Brought forward,	684 ft.
Strong limestone	5
Mixed gray and brown shales	12
Concretionary limestone	4
Soft blue clay	3
Slaty limestone in layers, one to two inches thick	47
Soft blue marl, with gypsum near the bottom	32
Gypsum	8
Soft green marl	3
Marl, with layers of limestone	28
Coarse limestone and shales	44
Crumbling porous limestone	50
Calcareous breccia, containing partially worn fragments of red syenite	24
Limestone showing no lines of bedding—*Terebratula sacculus*, *Productus cora*, fragment of *Avicula*	60
Compact slaty limestone	6
Soft brown shale	6
Brown and purple marls	40
	1056 ft.

In this section the Lower Carboniferous rocks are of much less aggregate thickness than usual; yet they display the several dissimilar members of the series pretty fully. The "millstone-grit" corresponds with the deposit of the same name overlying the Carboniferous limestone of England. It also corresponds with the thick succession of sandstones between Plaister Cove and Ship Harbour, with those overlying the gypsiferous rocks in Pictou county, with the sandstones of the Eagle's Nest, on the Shubenacadie, and with the lower groups of Mr Logan's Joggins section. The limestone, marls, and gypsum are well developed, except that the latter is of smaller thickness than is usual. The lower conglomerate is wanting; but this is always an irregular deposit, and it appears in its proper place in most other sections in this part of Cape Breton, as, for instance, at St Ann's Harbour, where the gypsum also is very largely developed. This section, as described by Mr Brown, did good service in confirming the new and more accurate views of the structure of the Carboniferous rocks in this province promulgated by Sir C. Lyell in 1842.

Useful Minerals of N. Inverness and Victoria.

Gypsum and *limestone* are very abundant in this district. The former may be obtained in any quantity at Mabou, Margarie River,

St Ann's, Big Harbour on the Great Bras d'Or, etc. The latter abounds in the same localities, as well as in several others where the gypsum is absent. The altered limestone at Craignish and Long Point would afford several pretty and unusual varieties of coloured *marble*.

Coal occurs at Port Hood, and since the publication of the first edition of this work, in which I directed attention to this coal-field as one of promise, it has been reported upon by Professor C. H. Hitchcock, and opened on a small scale. The principal bed is stated by Rutherford to be about 6 feet in thickness, with 4 feet 2 inches to 4 feet 4½ inches of good coal. Other valuable beds are said to have been found at Mabou, Broad Cove, and Chimney Corner; but they have not yet been opened.

In Victoria county the only mine now worked is that of New Campbelltown, on the Great Bras d'Or. At this place the Coal measures are stated to rest against the mass of syenitic or gneissose rock of Cape Dauphin, and to be in part in a nearly vertical position. In the principal workings of the mine two beds of coal have been opened up. They are separated from each other by a thickness of 36 yards. The upper is 4 feet thick, the lower 6 feet. In another part of the area, a bed 4 feet 5 inches thick has been found. Its identity with either of the above mentioned has not yet been ascertained.*

The yield of the Port Hood Mine for 1866 is stated to be 3824 tons, that of the New Compbelltown Mine 3142 tons.

Freestone for building is obtained, of good quality, at Port Hood Island and Margarie, and also at Whykokomagh; but it is not yet worked on a large scale.

The soils of this district being based principally on the calcareous rocks of the Lower Carboniferous series, are in general of excellent quality.

Carboniferous District of Cape Breton County.

This, though the last, is one of the principal Carboniferous districts of the province, as it includes the important and productive Coal-fields of Sydney, Lingan, Glace Bay, Cow Bay, and Miré, and exceeds all the others in its export of coal, while it scarcely yields to the Joggins in its excellent exposures of the Coal formation rocks and fossils. As we owe most that is known of this district to the labours of R. Brown, Esq. of Sydney, I shall avail myself, in the first instance, in describing it, of the information contained in his papers;† adding such other items of information as I have collected in short visits to this interesting

* Rutherford. † See List in Chapter I.

district, and the results of the important explorations for coal recently carried on, more especially in its eastern part.

The island of Boulardarie, the whole of which I include in this district, though politically a part of it belongs to Victoria county, consists in its western part of the Lower Carboniferous limestone, and overlying hard sandstones, having apparently an undulating arrangement, as represented by Mr Brown in his section of the island. The limestone, as I have observed it on the north side of Boulardarie, is hard and compact, and contains the *Productus semireticulatus*. At the eastern end of the island, the limestone and millstone-grit dip to the N.E. and underlie the Coal measures which appear near Point Aconi. The Coal measures, extending from Point Aconi to the outcrop of the millstone-grit, are stated by Mr Brown at 5400 feet in vertical thickness.

Crossing the Little Bras d'Or, the Coal measures continue with north-easterly dip across the peninsula separating this strait from Sydney Harbour, and thence with various faults and disturbances to Miré Bay. As the general dip is seaward, Mr Brown remarks, "this great area of Coal measures is probably the segment only of an immense basin, extending toward the coast of Newfoundland; a supposition which is confirmed by the existence of Coal measures at Neil's Harbour, 30 miles north of Cape Dauphin." Inland of this broad band of Coal measures, the whole country northward of a line drawn west from Miré Bay to the east arm of the Bras d'Or Lake, is occupied by the older members of the series, with the exception of a tract of syenitic, porphyritic, and altered rocks, which appears at and near George's River on the south-east side of Little Bras d'Or. These igneous rocks have altered the Lower Carboniferous limestone, as well as perhaps some underlying beds of the same system, showing that igneous action had not terminated in these ancient metamorphic districts at the commencement of the Carboniferous period; and this appears to have been the case along the boundary of the metamorphic and igneous rocks in many parts of Cape Breton.

This extensive Carboniferous district is connected with that of Richmond county on the south, by a very narrow stripe of limestone, red conglomerate, and sandstone, skirting the base of the hills of porphyry, syenite, and slate, rising steeply from the side of the Bras d'Or Lake, which here is a broad and beautiful inland sea, presenting fine scenery in almost every direction. The limestone and conglomerate may be seen in several places to rest on the edges of the older slates, and in some places, especially at Irish Cove, the former rock is filled with well-preserved fossil shells, including immense quantities of the *Conularia*, which in most other localities is rather rare; as well as *Produc-*

tus cora, *Terebratula sacculus*, *Spirifer glaber*, and a species of *Euomphalus*. The limestone is sufficiently soft to allow fine specimens of these shells to be detached by weathering.

The Coal measures are by far the most interesting part of this area, and are well exposed on the north side of Sydney Harbour, and on the south end of Boulardarie. Mr Brown has published an elaborate section and description of them as they occur at the former place, from which the following facts are gleaned:—

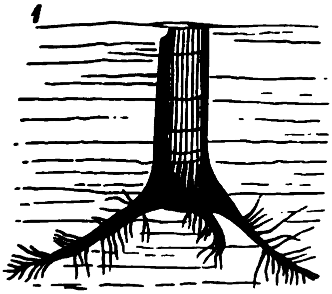
"The productive Coal measures cover an area of 250 square miles; but, owing to several extensive dislocations, it is impossible to ascertain their total thickness with any degree of accuracy; from the best information in my possession, I conclude that it exceeds 10,000 feet. We have one continuous section on the north shore of Boulardarie Island, 5400 feet in thickness, and in the middle portion of the field several detached sections, varying from 1000 to 2000 feet in thickness, whose exact relative positions have not yet been determined; although it is quite clear that they are higher up in the formation than the highest beds of the Boulardarie section."

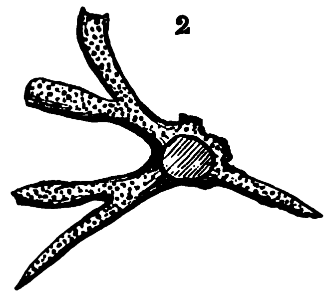
Mr Brown then proceeds to describe the section on the north-west side of Sydney Harbour, from Stubbard's Point to Cranberry Head, a distance of 5000 yards, and exhibiting a vertical thickness of 1860 feet of beds. The dip is N. 60° E. 7°. Of these beds he gives a detailed section, including 34 seams of coal, and 41 underclays with Stigmaria or fossil soils. The whole of the beds composing the section are summed up as follows:—

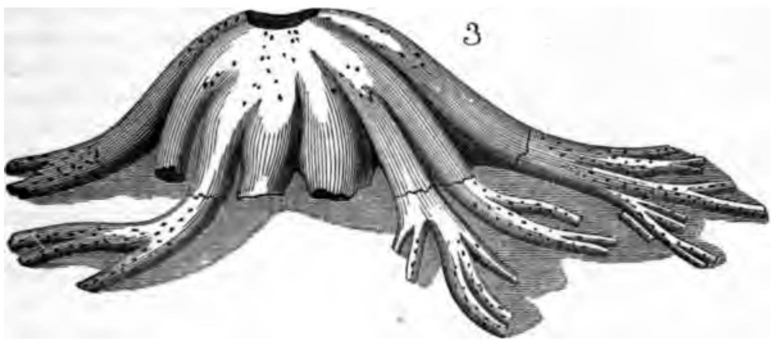
Arenaceous and argillaceous shales .	1127 ft.	3 in.
Underclays	99	6
Sandstones	562	0
Coal	37	0
Bituminous shales	26	5
Carbonaceous shales	3	3
Limestones	3	11
Conglomerate	0	8
	1860 ft.	0 in.

Erect trees and calamites occur at eighteen distinct levels. The greater number are Sigillariæ, many of them with distinct Stigmaria roots, and a few are Lepidodendra. They occur in circumstances very similar to those of the erect trees at the Joggins already described. Mr Brown's various papers on these fossils gave to the geological

ERECT SIGILLARIÆ AND STIGMARIAN ROOTS.







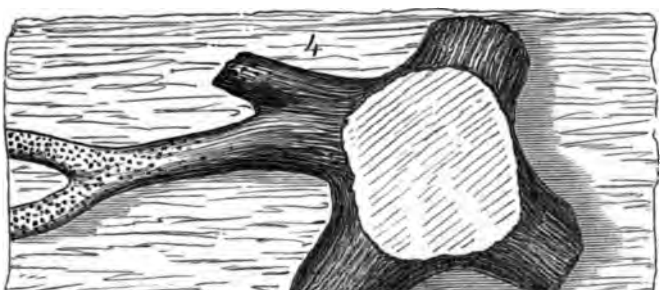


Fig. 1. ***Sigillaria in situ,*** **with Stigmaria Roots and Rootlets—Sydney.**
„ 2. Roots of the same, as seen in a horizontal Section—Sydney.
„ 3. Stump of ***Sigillaria Sydnensis,*** **showing the stem compressed into a dome—1-12th nat. size—Sydney.**
„ 4. Stump of ***Sigillaria,*** **with very regular Stigmarian Roots spreading in Sandstone —Port Hood.**

Figs. 1, 2, 3, are from papers by Mr Brown, quoted in the text. See also pp. 180, 432.

world the first really satisfactory information* respecting the true nature and mode of growth of Stigmaria; and to these I may refer the reader, more especially to that in volume fifth of the "Geological Journal," page 355, from which I quote the following account of a fine specimen of *Sigillaria alternans* with Stigmaria roots, regularly ramifying, and having attached to them conical tap roots, which penetrated directly downwards into a thin bed of shale overlying the main coal. This seam, like the main seam at the Joggins, has, when it was a bed of soft peat, supported a forest of Sigillariæ and Lepidodendra, many of which still remain erect in the overlying shale, with all their roots and long spreading rootlets attached.

"Immediately over the coal there is a bed of hard shale, six inches in depth, in which no fossils are found; this is overlaid by a *softer* shale abounding in coal-plants; all the upright trees that I have examined are rooted in the six-inch shale; the crown of the base of that which I am now describing is just four inches above the coal; its roots dip gradually downwards until they come in contact with the coal, at about eighteen inches from the centre of the tree, and then spread out over its surface. When this fossil was brought out of the mine the under side was covered up with hard shale, to which about one inch of coal adhered; in cutting away this layer of coal, I met with the termination of a perpendicular root immediately in contact with the coal, which I carefully developed; proceeding in this manner, my patience was amply rewarded by the discovery of a complete set of conical tap roots. The horizontal roots branch off in a remarkably regular manner, the base being first divided into four equal parts by deep channels running from near the centre; an inch or two farther on, each of these quarters is divided into two roots, which, as they recede from the centre, bifurcate twice within a distance of eighteen inches from the centre of the stump.

"There are four large tap roots in each quarter of the stump, and, about five inches beyond these, a set of smaller tap roots, striking perpendicularly downwards from the horizontal roots, making forty-eight in all: namely, sixteen in the inner, and thirty-two in the outer set; and what is a still more remarkable feature in this singular fossil, there are exactly thirty-two double rows of leaf-scars on the circumference of the trunk. This curious correspondence in the numbers of the roots and vertical rows of leaf-scars, surely cannot be accidental. I am not aware that any similar correspondence has

* Mr Binney can claim priority in date of publication; but his specimens were much less perfect in details of structure, and therefore less satisfactory than those described by Mr Brown.

ever been observed either in recent or fossil plants. The inner set of tap roots vary from two to two and a half inches in length; the diameter at their junction with the base of the trunk being about two inches. The outer set are much smaller, being about one inch in diameter at their junction with the horizontal roots, and from one to one and a half inch in length. Very few of either set are strictly conical, although they probably were originally of that shape; some are squeezed into an elliptical, others into a triangular form; all have been wrinkled horizontally by the shrinkage due to vertical compression. A thick tuft of broad flattened rootlets radiates from the terminations of the tap roots, and a few indistinct areolæ are visible on their sides; the length of these rootlets does not appear to exceed three or four inches, their width being one-fourth of an inch; a raised black line runs down the middle of each, similar to that observed in the rootlets of Stigmariæ. These short thick tap roots were evidently adapted only to a soft wet soil, such as we may easily conceive was the nature of the first layer of mud deposited upon a bed of peat, which had settled down slightly below the level of the water.

"We may infer also, from the existence of a layer of shale without fossil plants, immediately over the coal, that the prostrate stems and leaves which occur in such large quantities in the next superincumbent bed, fell from trees growing upon the spot, and were entombed in layers of mud held in suspension in water, which at short intervals inundated the low marshy ground on which they grew; for had the plants been drifted from a distance, we should find them in the first layer of shale as well as in those higher up.

"Although the main coal is generally overlaid by shale, yet occasionally the shale thins out, and the thick sandstone, which is the next stratum in the ascending order, forms the roof of the coal. In such cases the surface of the peat-bog could not have been level when the shale was deposited upon it, some small patches having been still above water; and as no upright trees are found in the sandstone roof, it may reasonably be inferred that plants would not vegetate upon the bog itself, a layer of soft mud being necessary in the first instance for germinating the seeds; but when a plant had once taken root in this mud, its rootlets penetrated downwards into the peat, and furnished an abundant supply of nutriment for the rapid growth of the tree, from the rich mass of decaying vegetable matter beneath."

The Sydney Coal measures contain not only erect trees, but also numerous beds with *Naiadites*, *Cythere*, *Spirorbis*, *Fish-scales*, etc.; though these do not so frequently overlie coal-seams as at the Joggins. The shales at Sydney are also much more rich than those at the Joggins in

the leaves and other more delicate parts of plants; and on this account I give here sketches of a few examples of the foliage of the Coal formation period, as displayed in the rocks of Nova Scotia and Cape Breton (Fig. 156). On the mode of occurrence of such leaves, Mr Brown remarks:—

"The shales are the most prolific in plants, especially those which form the roofs of the coal-seams. It is singular that not even a trace

Fig. 156.—*Foliage from the Coal formation.*

a b c d e f g.

(*a*) Alethopteris heterophylla (fern)—Moose River. (*b*) Sphenophyllum Schlotheimii—Pictou (*c*) Lepidodendron binerve—Sydney. (*d*) Asterophyllites foliosa—Sydney. (*e*) Cordaites borassifolia—Joggins. (*f*) Neuropteris rarinervis (fern)—Sydney. (*g*) Odontopteris subcuneata (fern)—Sydney.

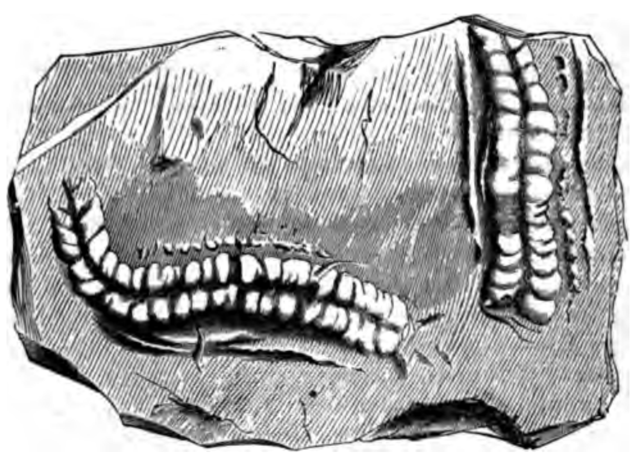
of a fossil plant nor any organic substance has been found in any of the red shales, although they have been carefully examined for that purpose.* Wherever erect trees occur, ferns, Asterophyllites, Sphenophylla, and other delicate leaves, are found in the greatest abundance; from which I infer that they fell from growing trees and shrubs, having been covered up by successive layers of fine mud, deposited at frequent intervals over a low marshy district. In these localities single fronds of ferns are sometimes found covering a slab of shale two feet square, as sharp and distinct in their outline as if they had been gathered only yesterday from a recent fern, and spread out with the greatest possible care, not a single leaflet being wanting or even

* This does not apply to the Coal formation of Pictou, where ferns, Cordaites, and Sphenophyllum are found in red shales, though rarely.

doubled up. Some beds also seem to contain one species of plant only, all others being excluded; of this we have a striking example in the argillaceous shale (No. 60): in the top of this bed, through a thickness of three inches, we find Asterophyllites foliosa, piled up layer above layer, from the base of the cliff to the crop of the bed—a distance of 200 feet—clearly proving that these plants grew on the spot." This description may give the reader some idea of the abundance and perfection of the fossil vegetation preserved in the Sydney Coal measures. As already stated also, a bed of shale in the Sydney section has afforded the finest example yet known of carboniferous rain-marks. These occur in a bed at the top of one of those bands in which the sandstones are rippled and fossils rare. At some distance below it there are mussel shales, and ten feet above a stigmaria underclay and coal. These marks then were preserved in beds formed during the transition from aquatic to terrestrial conditions, by the silting up of a lagoon or creek, and most probably on a bed daily left dry at low tide.

In a previous chapter mention was made of the curious footprints called *Rusichnites*, as occurring in the Lower Carboniferous. In the Cape Breton Coal-field an interesting species occurs in the Coal measures (Fig. 157). The specimen from which the figure was taken was kindly presented to me by R. Brown, Esq.

Fig. 157.—*Rusichnites Acadicus*—Dawson



Each impression consists of the casts of contiguous rounded furrows, each about one-eighth of an inch in breadth, and crossed by curved

undulations and striæ, in such a manner as to give the appearance of a pinnate leaf carved in high relief. At each side of these impressions, and about a tenth of an inch distant from them, are interrupted lines, in relief in the casts, and running parallel with the casts of the furrows. The whole has exactly the appearance of the track of the swimming feet and edges of the carapace of a small *Limulus*, or King-crab. The tracks have also the same tortuous character with those of the modern Limulus. *Limuli* have not yet occurred in the Coal formation of Nova Scotia, though they occur in rocks of this age elsewhere; but from these tracks I infer that animals of this kind lived in the Sydney Coal-field, where their remains will probably hereafter be found. I have proposed for these impressions the name *R. Acadicus*, in a paper on footprints of this class in the "Canadian Naturalist."

Useful Minerals of the Carboniferous District of Cape Breton County.

Coal ranks at the head of these, about 421,000 tons being raised annually from the coal beds of this district. The oldest colliery in the district is that of North Sydney, which is worked by the General Mining Association, on the north side of Sydney Harbour. The coal is shipped at the bar at North Sydney, to which place a railway has been laid. The coal from this mine is used principally for domestic fires, and for the production of steam, for which it is admirably suited.

Of the thirty-four seams included in Mr Brown's Sydney section, only four are of workable thickness; they are,—

1. The Indian Cove seam, about 450 feet of vertical thickness below the main seam	4 ft.	8 in.
2. The main seam	6	9
3. The Lloyd's Cove seam, about 730 feet of vertical thickness above the main seam	5	0
4. The Cranberry Head top seam, about 280 feet above Lloyd's Cove seam	3	8

Of these only the main seam is worked at present, at the North Sydney mines. It yields a bright, free-burning coal, giving out its heat very rapidly, and leaving a very small quantity of heavy reddish ashes. According to Professor Johnston, it yields,—

Volatile matter	26·93
Fixed carbon	67·57
Ashes	5·50
	100·000

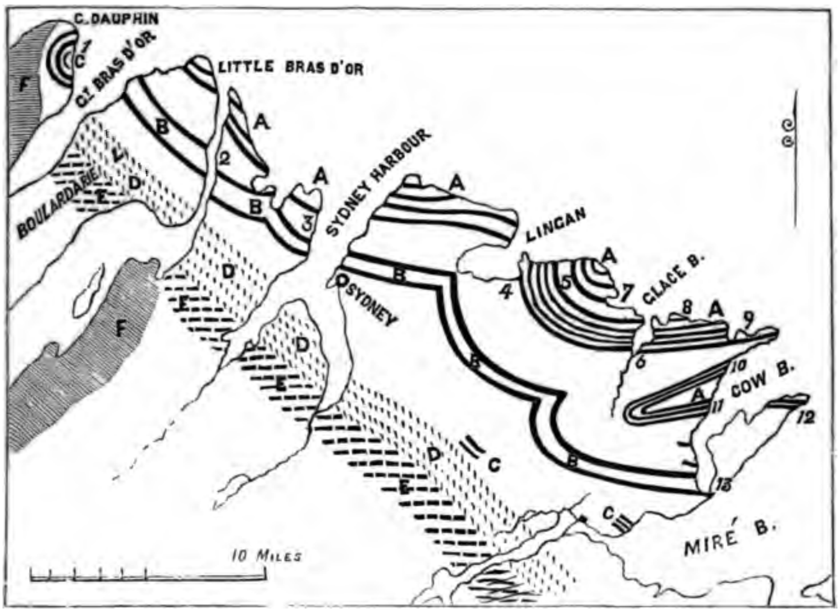
Its steam-producing power is rather less than that of Pictou coal, being, according to the same authority, 7·01 to 1 lb., or from the temperature of 212°, 7·99 to 1 lb. It also yields less illuminating gas; and, from the presence of a little bisulphuret of iron, is more destructive to furnace bars than Pictou coal. For domestic use, however, its comparative freedom from dusty ashes more than compensates for these defects.

North-westward of Sydney, the Coal measures extend to the Little Bras d'Or, and across the east end of Boulardarie Island; but this part of the district does not appear to be productive at present, though without doubt rich in coal. To the south-east of Sydney the Coal measures extend in a series of anticlinal and synclinal bends to Miré Bay and Catalogne, and are extensively worked, though, from facts to be noted in the sequel, it will appear that their maximum productiveness is still very far from being reached. The sketch map (Fig. 158) will show the general arrangement of the measures, as far as ascertained, and the localities of the principal mines.

When the first edition of this work was published, little was known of the extension of the Coal measures along the coast of Cape Breton from Sydney to Miré, except the mere fact of the extension of the Coal formation rocks, and the occurrence in them of some workable beds, to which, however, little attention had been given; partly in consequence of the monopoly of the General Mining Association, and partly in consequence of the absence of facilities for the shipment of coal. Within the last few years, however, the whole coast has been explored by mining surveyors, and fourteen important mines have been opened or are in progress.

As in many other parts of the Carboniferous area of Acadia, the Coal formation beds are undulated along a series of anticlinal and synclinal lines, the synclinals running out at the surface as they approach the older rocks, an arrangement which has been well worked out in detail by Professor Lesley, in his reports on the district. In this way the coal rocks of Eastern Cape Breton appear as the ends of three troughs. The most eastern and narrowest is that of Cow Bay. It is separated from the second, that of Glace Bay, by an east and west anticlinal running out to the shore at North Head or Cape Granby. The Glace Bay trough is wider and flatter, and is separated from the still broader trough of Sydney by a second anticlinal running out at Lingan. In consequence of this arrangement and the inequalities of the coast line, the beds are repeated a number of times, and only a limited portion of the whole thickness of the Carboniferous system is

Fig. 158.—*Map of Cape Breton Coal-field.*



A, Upper Coal beds.	4. Lingan Mine.
B, Middle Coal beds.	5. International "
C, Lowest Coal beds.	6. Caledonia "
D, Millstone-grit.	7. Little Glace Bay "
E, Lower Carboniferous.	8. Clyde "
F, Metamorphic Silurian.	9. Schoner Point "
	10. Block House "
1. New Campbellton Mine.	11. Gowrie "
2. Little Bras d'Or "	12. South Head "
3. Sydney "	13. Miré "

Note.—It should be observed that there are probably several beds of coal between series A and series B, and that the lines of outcrop of series B, C, D, and E, are not known in detail.

exposed in the coast sections, but great facilities are afforded for exploring and working the beds of coal.

Professor Lesley has published (Proc. Am. Acad., Phila. 1862), a detailed section of that part of the series exposed in the vicinity of Little Glace Bay, amounting to a thickness of 907 feet. Unfortunately he gives no information as to the fossils, and appears to have been under the impression that his section includes nearly the whole of the productive Coal measures of Cape Breton, so that it is not possible to form any definite idea of the place in the series to which these beds belong. From specimens and information obtained from Mr Poole, Mr Barnes, Mr Mosely, and others, I am inclined to regard them as being in the upper part of the Middle Coal formation, the Upper Coal formation being apparently wanting or concealed under the ocean, and the Millstone-grit series appearing farther inland.

Professor Lesley's section may be condensed as follows. It commences at the headland between Burnt Head and Little Glace Bay, where the newest rocks seen on this part of the coast appear.

		ft.	in.
	Shales red and gray, the latter with nodules of iron ore	85	6
	Sandstone and arenaceous shale	14	0
Coal-group 1	*Coal*, good	1	0
	Underclay and sandstone	6	0
	Carbonaceous shale	2	0
	Underclay	8	0
	Shale	41	6
Coal-group 2	*Coal*, soft	1	6
	Coal, solid—"Hub Vein"	4	0
	Coal, hard	1	0
	Sandstone with fossil plants	20	0
Coal-group 3	*Cannel Coal*,	1	6
	Underclay	6	0
	Cannel Coal	0	6
	Underclay	2	6
	Sandstones and shales	25	0
Coal-group 4	*Cannel Coal*	0	1
	Underclay	3	0
	Shale, arenaceous shale and sandstone	133	11
Coal-group 5	*Coal*	0	0½
	Shale	6	0
	Coal and carbonaceous shale	0	6
	Underclay	5	0
	Shale and sandstone	69	6
Coal-group 6	Clay	0	3
	Cannel Coal,	0	1
	Underclay	7	0

		ft.	in.
	Shales and arenaceous shales	11	8½
Coal-group 7	Dark shale	0	6
	Coal slate "Cannel"	0	6
	Hard sandy shale	0	8
	Coaly matter	0	0½
	Hard sandy shales and fire-clay	11	0
	(A slight break in the section occurs here in Little Glace Bay).		
	Soft measures	10	0
Coal-group 8	Coaly shale	0	4
	Coal	0	3
	Sandstones and shales	93	6
Coal-group 9	Black bituminous shale	0	5
	Cannel Coal	0	1
	Black bituminous shale	0	6
	Underclay	1	0
	Sandstone and fire-clay	19	0
Coal-group 10	*Coal*, "Harbour Vein."	5	0
	Shales foliated	8	0
	Iron ore	0	3
	Coal	0	8
Coal-group 11	Shale and sandstone	14	6
	Coal	2	0
	Sandstones, shales, and fire-clay	112	0
Coal-group 12	*Coal*	0	0½
	Black shale	0	6
	Sandstones, shales, and fire-clay with nodules of Ironstone	104	0
Coal-group 13	*Coal* "Brutether's Vein" *	2	0
	Underclay	2	0
	Shales, sandstones, and fire-clays, the latter with nodules of ironstone	49	6

In all, 907 feet.

The above section is thus continued in descending order by the following, kindly furnished by H. Poole, Esq., from the Engine Pit at the Caledonia Mine:—

		ft.	in.
	Gray sandstone underlaid by seven inches of gray shale with fossil plants	9	4
Coal-group 14	*Coal*	1	2
	Black shale with fossils	0	7
	Gray sandstones with *Stigmaria*, underlaid by dark gray shale ten inches	19	0
Coal-group 15	*Coal* with partings of shale and fire-clay "Back Pit Seam."	4	9
	Hard gray sandstone	1	0
	Gray sandstone with beds of fire-clay—*Stigmaria*	64	7
Coal-group 16	*Coal* two to nine inches	0	5
	Dark gray sandstone—*Stigmaria*	1	6
	Sandstone and shale—*Stigmaria*, *Neuropteris*, *Cordaites*	27	8

* According to Mr Poole, the perpendicular distance between Coal-groups 12 and 13 is 135 feet, and there are two coals, each one foot thick, in the interval.

		ft.	in.
Coal-group 17	*Coal*	0	2
	Black shale, fossils	0	10
	Coal	0	12
	Black shale—*Sigillaria*	0	9
	Coal, pyritous	0	1
	Black shale, fossils	0	10
	Soft shale—*Stigmaria*	0	4
	Sandstone, shale and calcareo-bituminous shale, with *Lepidodendra*, *Cordaites*, *Sigillaria*, and *Stigmaria*—also shells of *Naiadites*, *Spirorbis*, and *Cyprids*	14	7
Coal-group 18	*Coal* "Phelan Seam"	8	3
	Dark gray sandstone—*Stigmaria*	4	1
	In all, 178 feet.		

The Phelan bed is, on the best evidence, identified with the Bridgport or Lingan bed on the west, and the M'Aulay bed at Cow Bay on the east. Assuming this to be correct, the following table gives the continuation of the section, as shown in a MS. report of Mr Mosely of Halifax, kindly communicated to me by Mr Joseph B. Moore:—

		ft.	in.
	Sandstones and shales	100	0
Coal-group 19	*Coal*	0	7
	Measures not described	42	0
Coal-group 20	*Coal*	0	7
	Measures not described	63	0
Coal-group 21	*Coal*	1	4
	Sandstones, shales, and ironstone	58	0
Coal-group 22	*Coal* "M'Phail or M'Rury Seam" *	5	6
	Sandstone and shale	100	0
Coal-group 23	*Coal*	3	0
	Shales and fire-clay	92	0
Coal-group 24	*Coal*	2	8
	Measures undescribed	50	0
Coal-group 25	*Coal*	4	4

* In Mr Lyman's Report, the latter part of this section is given somewhat differently, as follows:—

M'Rury coal	4 ft. 4 in. to 5	ft. 4 in.
Measures undescribed	150	0
Coal (two feet bed)	1 ft. 9 in. to 2	3
Measures undescribed, about	100	0
Coal (eighteen-inch bed)	1	6
Measures undescribed, about	100	0
Coal ("Long Beach Bed")	2	10
Measures undescribed	2400	0
Coal ("Tracey Bed")	4	12

The bed three feet thick about 100 feet below the M'Rury Seam appears to have been discovered after the publication of Lyman's Report; and Mr Poole mentions a bed one foot thick as occurring between the former and the "M'Rury."

		ft.	in.
	Sandstone and shale	100	0
Coal-group 26	*Coal* "Long Beach Seam"	3	8
	Measures not described	50	0
Coal-group 27	*Coal*	2	3
	Sandstone and shale	105	0
Coal-group 28	*Coal*	1	6
	Measures not described	(?) 103	0
Coal-group 29	*Coal*	6	0

Below this last bed, the Coal measures continue to occupy the country for some distance, and a bed 4 feet thick, the "Gardener Coal," occurs 330 feet lower. At a distance estimated by Mr Lyman at 2400 feet below the Long Beach Seam, or about 2130 feet below coal No. 29, mentioned above, occurs a bed of good coal, three feet eight inches and a quarter in thickness, or, including a clay parting, which appears in some portions, but not in others, four feet one inch and a half. It is called the "Tracey Seam." Another seam is indicated in Mr Poole's and Mr Mosely's plans, between the "Tracey" and seam 29 above, and 435 to 460 feet above the former; but I have no information in respect to it. The Tracey bed is now worked on the peninsula between Cow and Miré Bays, and is the most eastern coal worked in this coal-field. To the southward of it, however, and at a distance representing at least a thousand feet of beds, there is said to be still another coal known as the "Spencer Seam," before we reach the beginning of the Millstone-grit series, which would thus seem to be at least 4500 feet below the newest beds seen near Glace Bay.

An important question arises here as to the equivalency of any of these beds with the Coal measures of North Sydney. Mr R. Brown, in the remarks prefixed to his section of the Sydney Coal-field in 1849, states his belief that the beds at Glace Bay are newer than those of North Sydney. Mr Lesley, on the other hand, regards them as equivalent. After a careful comparison of the several sections, I confess that I think the view of Mr Brown the more probable; more especially as it places these beds more intelligibly in relation with the members of the Lower Carboniferous seen farther inland, and with the other coal-fields of Nova Scotia. From Mr Brown's section, it would appear that the Sydney main coal is only about 800 feet above the beginning of the Millstone-grit formation; and one considerable bed, the Indian Cove seam, of 4 feet 8 inches in thickness, occurs in this interval with a thickness of 350 feet between it and the Millstone-grit. Now, as the latter formation is not brought to the surface by either of the anticlinals between Sydney and Miré, and does not appear for some distance up Miré Bay, it seems plain that the only beds in our sections

which can represent the Sydney main coal and the Indian Cove seam, must be the Tracey and Spencer beds, or beds associated with them, and not yet well known.* In this case the whole of the upper beds at Cow Bay and Glace Bay beds must actually overlie the Cranberry Head seam at Sydney, which may be about the horizon of the Phelan bed. The only supposition which would enable us to arrive at any other conclusion is, that the 2000 feet of thickness between the six-feet bed and Tracey bed represent the Millstone-grit of Mr Brown; but as that careful observer mentions no beds of coal under the Millstone-grit, and states that a continuous section of 5400 feet of Coal measures exists on the north side of Boulardarie Island, this is scarcely possible.

In this view of the case, then, the total thickness of Coal measures from the Millstone-grit to the newest beds between Glace Bay and Lingan cannot be less than 4500 to 5000 feet, and may be more; and it is probable that several important coals not yet known exist in the lower part of these measures.

In comparison with the Joggins section, it would appear that we have in these Coal measures of Cape Breton a complete equivalent of Divisions 3 and 4 of the former section, with a greater aggregate thickness of coal; and if we make allowance for the probability that many of the smaller beds in Cape Breton have not been noticed by explorers, probably quite as many beds of coal.

It is a matter of some practical importance that the question raised by the discrepancy of the views of Mr Brown and Mr Lesley above stated should be definitely settled by the actual tracing of some of the beds above referred to into connexion with the Sydney area. If Mr Brown's view should prove correct, the available coal of the district will be double that represented by Lesley, and other and very valuable discoveries may be anticipated in the country between Miré Bay and Sydney Harbour.

From the Report of the Commissioner of Mines for 1866, it appears that there are fourteen distinct mining establishments now operating in the Coal-field of Eastern Cape Breton, and producing an aggregate of more than 400,000 tons of coal annually, or nearly two-thirds of the whole quantity raised in the province of Nova Scotia, so that this is now the most important coal-mining district in the Acadian provinces.

Some of the coals of this district are of remarkable purity, in so far

* Mr Mosely, in a letter to the author, mentions some strong reasons for believing that the Tracey bed is the equivalent of Mr Brown's third seam, or Indian Cove seam at Sydney, and that a bed seen at Black Brook, head of Cow Bay, is the Sydney main seam, being at the same vertical distance above the Tracey that the Sydney main is above the Indian Cove seam.

as freedom from ash is concerned; and that of Lingan is remarkable for its large yield of illuminating gas. I am indebted to Mr Poole for the following table of results of assays of the coal of the Caledonia Mine:—

Wayland Seam, Caledonia Coal Mine, Glace Bay, Cape Breton, November 1866.

Number of Sample.	Depth in Seam.	Specific Gravity.	Vol. Matter.	Coke.	Carbon.	Ash.	Colour of Ash.
	Ft. in.						
1	0 6	1·365	33·412	66·588	60·880	5·708	Pale brown.
2	1 6	1·433	30·408	69·592	51·771	17·821	Pale brown.
3	2 6	1·287	27·098	72·902	57·358	15·544	Gray.
4	3 6	1·321	30·792	69·208	55·625	13·583	Brown.
5	4 6	1·298	33·826	66·174	61·174	5·000	White.
¼ in. parting, 6	5 3	1·452	30·709	69·291	45·705	23·586	White.
7	5 6	1·296	36·728	63·272	58·494	4·778	Light brown.
8	6 6	1·324	37·567	62·433	55·868	6·565	Reddish brown.
9	7 6	1·311	34·225	65·775	57·772	8·003	Brown.
Total...	8 0	12·087	294·765	605·235	504·647	100·588	
Less parting,	No. 6	1·452	30·709	69·291	45·705	23·586	Parting ded.; not shipped.
	8 ÷	10·635	264·056	535·944	458·942	77·002	
Average...		1·329	33·007	66·993	57·368	9·625	

Clay Ironstone, in nodules, occurs in several of the shales of the Sydney section, and is also present in large quantity in the Coal measures of Glace Bay, but I have no information respecting its probable industrial value.

Limestone and *Gypsum*, as already mentioned, abound in a number of places, but are not extensively worked. An altered limestone, which extends from the neighbourhood of Long Island, on the Little Bras d'Or, toward the East Arm, affords a gray and white *Marble*. *Freestone* and *Grindstone* are also quarried, though in small quantity.

Plants from Glace Bay.

Since writing the chapter on the Cape Breton Coal-field, I have received from Hy. Poole, Esq., a collection of plants from the Coal measures of Glace Bay; among which I recognise the following forms:—

Cyperites.
Trigonocarpum.
Alethopteris nervosa.
Alethopteris Serlii.
Alethopteris allied to *Grandini*.
Alethopteris lonchitica.

Pecopteris oreopteroides (?)
Pecopteris Dournaisii, or allied.
Neuropteris flexuosa.
Neuropteris rarinervis.
Neuropteris auriculata.
Sphenopteris decipiens (?)
Cyclopteris fimbriata.

Asterophyllites equisetiformis.

Sphenophyllum—a species with seven or eight long narrow leaflets, each with about eight nerves. I have fragments of the same from Sydney. It is probably new, and is certainly different from the other species referred to in the text. It may be named *S. Pooli.*

Cordaites borassifolia.
Lepidodendron elegans.
Lepidodendron like *tetragonum.*
Lepidophyllum lanceolatum.

Associated with these plants are abundant valves of *Naiadites elongatus*, and also scales of small ganoid fishes and cyprids.

The flora represented by this collection is very like that of Sydney, more especially in the number of ferns and the species of those present; and it is probable that this resemblance will be found to extend throughout the Coal-field of Eastern Cape Breton. It is a strictly Middle Coal formation assemblage, though having the facies of the upper part of that series, to which the Glace Bay beds would, on stratigraphical grounds, be referred.

CHAPTER XX.

THE CARBONIFEROUS SYSTEM—*Continued.*

THE FLORA OF THE COAL FORMATION.

I HAVE already endeavoured to introduce the reader into the jungles and forests of Carboniferous Acadia; but in order that he may fully appreciate the nature of the wondrous vegetation of that ancient time, the producer of all our stores of mineral fuel, it will be necessary that we shall pass in review the several genera of Coal formation plants, and endeavour so to restore them that, in imagination, we may see them growing before us, and fancy ourselves walking beneath their shade. While thus endeavouring to introduce the ordinary reader and the student of Geology and Palæontology to an acquaintance with the Coal Flora, I shall take advantage of the abundant material within my reach to restore some of the species more completely than has hitherto been possible, and thus to present to geologists what I trust may prove a more full and accurate synopsis of the leading features of the Carboniferous Flora than any at present accessible.

The modern flora of the earth admits of a grand twofold division into the *Phænogamous*, or flowering and seed-bearing plants, and the *Cryptogamous*, or flowerless and spore-bearing plants. In the former series, we have, first, those higher plants which start in life with two seed-leaves, and have stems with distinct bark, wood, and pith—the *Exogens*; secondly, those simpler plants which begin life with one seed-leaf only, and have no distinction of bark, wood, and pith, in the stem—the *Endogens*; and, thirdly, a peculiar group starting with two or several seed-leaves, and having a stem with bark, wood, and pith, but with very imperfect flowers, and wood of much simpler structure than either of the others—the *Gymnosperms*. To the first of these groups or classes belong most of the ordinary trees of temperate climates. To the second belong the Palms and other trees found in tropical climates. To the third belong the Pines and Cycads. In the second or Cryptogamous series we have also three classes,—(1.) The *Acrogens*, or ferns and club-mosses, with stems having true vessels marked on the sides

with cross bars—the scalariform vessels. (2.) The *Anophytes*, or mosses and their allies, with stems and leaves, but no vessels. (3.) The *Thallophytes*, or lichens, fungi, sea-weeds, etc., without true stems and leaves.

In the existing climates of the earth we find these classes of plants variously distributed as to relative numbers. In some, pines predominate. In others, palms and tree-ferns form a considerable part of the forest vegetation. In others, the ordinary exogenous trees predominate, almost to the exclusion of others. In some Arctic and Alpine regions mosses and lichens prevail. In the Coal period we have found none of the higher Exogens, and only a few obscure indications of the presence of Endogens; but Gymnosperms abound, and are highly characteristic. On the other hand, we have no mosses or lichens, and very few algæ, but a great number of ferns and Lycopodiaceæ or club-mosses. Thus the Coal formation period is botanically a meeting place of the lower Phænogams and the higher Cryptogams, and presents many forms which, when imperfectly known, have puzzled botanists in regard to their position in one or other series. In the present world, the flora most akin to that of the Coal period is that of moist and warm islands in the southern hemisphere. It is not properly a tropical flora, nor is it the flora of a cold region, but rather indicative of a moist and equable climate. Still we must bear in mind that we may often be mistaken in reasoning as to the temperature required by extinct species of plants differing from those now in existence. Farther, we must not assume that the climatal conditions of the northern hemisphere were in the Coal period at all similar to those which now prevail. As Sir Charles Lyell has shown, a less amount of land in the higher latitudes would greatly modify climates, and there is every reason to believe that in the Coal period there was less land than now. Farther, it has been shown by Tyndall that a very small additional amount of carbonic acid in the atmosphere would, by obstructing the radiation of heat from the earth, produce almost the effect of a glass roof or conservatory, extending over the whole world. Again, there is much in the structure of the leaves of the Coal plants, as well as in the vast amount of carbon which they accumulated in the form of coal, and the characteristics of the animal life of the period, to indicate, on independent grounds, that the carboniferous atmosphere differed from that of the present world in this way, or in the presence of more carbonic acid,—a substance now existing in the very minute proportion of less than one-thousandth of the whole, a quantity adapted to the present requirements of vegetable and animal life, but probably not to those of the Coal period.

We shall commence our survey of the Coal flora with the higher forms of plant-life, which are also those most akin to the plants of the present world.

Class of Gymnosperms.

1. *Coniferæ or Pines.*

Four species of pines have been recognised in the Coal formation of Nova Scotia and New Brunswick. They are known principally as drift trunks imbedded in the sandstones, and these are so abundant as to indicate that extensive pine forests existed, perhaps principally in the uplands, higher than the Coal swamps. The trunks are also frequently so well preserved, owing to the infiltration of carbonate of lime or silica into their cells, that their most minute structures can be observed as readily as in the case of recent wood. They may all be included in the genus *Dadoxylon*, a name which means simply pine-wood. The wood of these trees, however, more resembles that of the Araucarian pines of the southern hemisphere than that of our ordinary pines.

One of the species, *D. antiquius*, is closely allied to *D. Withami* of Great Britain, and, like that species, belongs to the Lower Carboniferous Coal measures. Its structure is of that character for which Brongniart proposed the generic name "*Palæoxylon.*"* Another species, *D. Acadianum*, is found abundantly at the Joggins and elsewhere in the condition of drifted trunks imbedded in the sandstone of the lower part of the Coal formation and the upper part of the Millstone-grit series. The third species, *D. materiarium*, is very near to *D. Brandlingii* of Great Britain, and may possibly be only a variety. It is especially abundant in the sandstone of the Upper Coal formation, in which vast numbers of drifted trunks of this species occur in some places. The fourth species, *D. annulatum*, presents a very peculiar structure, probably of generic value. It has alternate concentric rings of discigerous woody tissue, of the character of that of *Dadoxylon*, and of compact structureless coal, which either represents layers of very dense wood or, more likely, of corky cellular tissue. In the latter case, the structure would have affinities with that of certain *Gnetaceæ* or jointed pines, and of Cycads.

Though coniferous trees usually occur as decorticated and prostrate trunks, I have recorded the occurrence of one erect specimen, in a sandstone a little above the "Main Coal," at the Joggins. It probably belonged to the species last named. Tissues of coniferous trees are very rare in the coal itself. Most of the tissues marked with discs on the cells like those of pines, found in the coal, belong to *Sigillaria* and

* Ancient wood.

Calamodendron. From the abundance of coniferous trees in sandstones above and below the coal, and their comparative absence in the coal and coal-shales, it may be inferred that these trees belonged rather to the uplands than to the coal-swamps; and the great durability and small specific gravity of coniferous wood would allow it to be drifted, either by rivers or ocean-currents, to very great distances. I am not aware that the fruits of pine-trees occur, unless some of those called *Trigonocarpa* are of this character. Nor has any foliage of these trees been found, except at Tatamagouche, in the continuation of the Upper Coal formation, where I have found leafy branchlets which I have named *Araucarites gracilis*, and which may possibly have belonged to *Dadoxylon materiarium.*

The casts or pith-cylinders known as *Sternbergiæ* are abundant in some of the sandstones, especially in the Upper Coal formation. I have shown that in Nova Scotia, as in England, some of these singular casts belong to *Dadoxylon*;* but as the pith-cylinder of *Sigillaria* and of *Lepidophloios* was of a similar character, those which are destitute of woody investment cannot be determined with certainty, though in general the transverse markings are more distant in the *Sternbergiæ* of *Sigillaria* and *Lepidophloios* than in those of *Dadoxylon.*

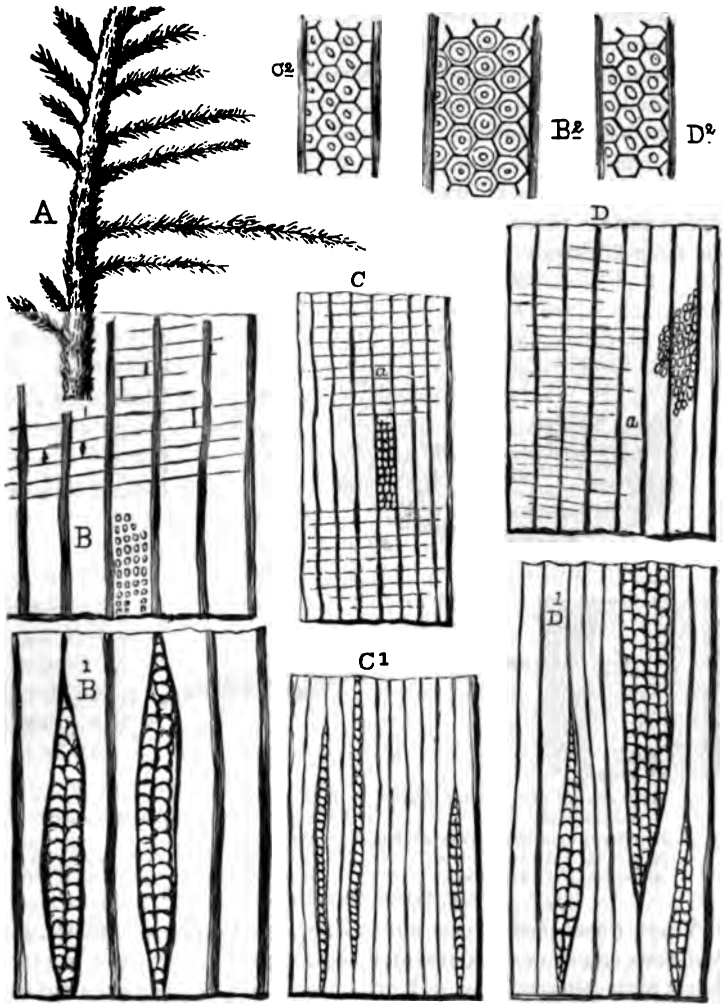
In a paper communicated to the Geological Society of London in 1846, to which Professor Williamson, in his able Memoir in the Manchester Transactions (vol. ix., 1851), assigns the credit of first suggesting that connexion between these curious fossils and the conifers which he has so successfully worked out, I stated my belief that those specimens of Sternbergiæ which occur with only thin smooth coatings of coal might have belonged to rush-like endogens; while those to which fragments of fossil wood were attached presented structures resembling those of conifers. These last were not, however, so well preserved as to justify me in speaking very positively as to their coniferous affinities. They were also comparatively rare; and I was unable to understand how casts of the pith of conifers could assume the appearance of the naked or thinly coated Sternbergiæ. Additional specimens, affording well-preserved coniferous tissue, have removed these doubts, and, in connexion with others in a less perfect state of preservation, have enabled me more fully to comprehend the homologies of this curious structure, and the manner in which specimens of it have been preserved independently of the wood.

My most perfect specimen is one from the coal-field of Pictou†

* Proceedings of the American Association, 1837, Canadian Naturalist, vol. ii. Paper on Structures of Coal, Quart. Journ. Geol. Soc. 1860.

† Presented to me by Mr Hogg of Pictou Island.

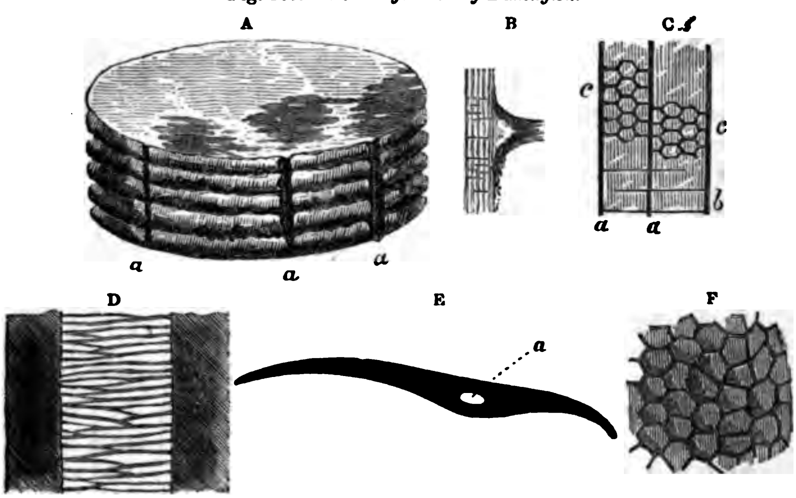
Fig. 159.—*Araucarites and Dadoxylon.*



A, Araucarites gracilis; reduced.
B, Dadoxylon Acadianum (radial), 90 diams.
B1, Do. do. (tangential), 90 diams.
B2, Do. do. cell showing areolation, 250 diams.
C, Dadoxylon materiarium (radial), 90 diams.
C1, Do. do. (tangential), 90 diams.
C2, Do. do. cell showing areolation, 250 diams.
D, Dadoxylon antiquius (radial), 90 diams.
D1, Do. do. (tangential), 90 diams.
D2, Do. do. cell showing areolation, 250 diams.

(Fig. 160). It is cylindrical, but somewhat flattened, being one inch and two-tenths in its least diameter, and one inch and seven-tenths in its greatest. The diaphragms, or transverse partitions, appear to have been continuous, though now somewhat broken. They are rather less than one-tenth of an inch apart, and are more regular than is usual in these fossils. The outer surface of the pith, except where covered by the remains of the wood, is marked by strong wrinkles, corresponding to the diaphragms. The little transverse ridges are in part coated with a smooth tissue similar to that of the diaphragms, and of nearly the same thickness.

Fig. 160.—*Sternbergia Pith of Dadoxylon.*



A, Specimen; nat. size, showing remains of wood at (*a*) (*a*).
B, Junction of wood and pith; magnified.
C, Cells of the wood of do. (*aa*); (*b*) Medullary ray; (*c*) Areolation.
D, Longitudinal section of another specimen with thick coaly envelope representing the wood.
E, Flattened trunk, with *Sternbergia* pith at (*a*); reduced.
F, Cellular tissue of pith.

When traced around the circumference or toward the centre, the partitions sometimes coalesce and become double, and there is a tendency to the alternation of wider and narrower wrinkles on the surface. In these characters and in its general external aspect, the specimen perfectly resembles many of the ordinary naked Sternbergiæ.

On microscopic examination, the partitions are found to consist of condensed pith, which, from the compression of the cells, must have been of a firm bark-like texture in the recent plant (Fig. 160, F). The wood attached to the surface, which consists of merely a few small splinters, is distinctly coniferous, with two and three rows of discs on

the cell walls (C, *c*). It is not distinguishable from that of *Pinites* (*Dadoxylon*) *Brandlingii* of Witham, or from that of the specimens figured by Professor Williamson. The wood and transverse partitions are perfectly silicified, and of a dark-brown colour. The partitions are coated with small colourless crystals of quartz and a little iron pyrites, and the remaining spaces are filled with crystalline laminæ of sulphate of barytes.

Unfortunately this fine specimen does not possess enough of its woody tissue to show the dimensions or age of the trunk or branch which contained this enormous pith. It proves, however, that the pith itself has not been merely dried and cracked transversely by the elongation of the stem, as appears to be the case in the Butternut (*Juglans cinerea*), and some other modern trees, but that it has been condensed into a firm epidermis-like coating and partitions, apparently less destructible than the woody tissue which invested them. In this specimen the process of condensation has been carried much farther than in that described by Professor Williamson, in which a portion of the unaltered pith remained between the Sternbergia cast and the wood. It thus more fully explains the possibility of the preservation of such hollow-chambered piths after the disappearance of the wood. It also shows that the coaly coating investing such detached pith-casts is not the medullary sheath, properly so called, but the outer part of the condensed pith itself.

The examination of this specimen having convinced me that the structure of Sternbergiæ implies something more than the transverse cracking observed in Juglandaceæ, I proceeded to compare it with other piths, and especially with that of *Cecropia peltata*, a West Indian tree, of the natural family Artocarpaceæ, a specimen of which was kindly presented to me by Professor Balfour of Edinburgh, and which I believe has been noticed by Dr Fleming, in a paper to which I have not had access. This recent stem is two inches in diameter. Its medullary cylinder is three-quarters of an inch in diameter, and is lined throughout with a coating of dense whitish pith tissue, one-twentieth of an inch in thickness. This condensed pith is of a firm corky texture, and forms a sort of internal bark lining the medullary cavity. Within this the stem is hollow, but is crossed by arched partitions, convex upward, and distant from each other from three-quarters to one and a quarter inch. These partitions are of the same white corky tissue with the pith lining the cavity; and on their surfaces, as well as on that of the latter, are small patches of brownish large-celled pith, being the remains of that which has disappeared from the intervening spaces. Each partition corresponds with the upper margin of one of the large

triangular leaf-scars, arranged in quincuncial order on the surface of the stem.

Inferring from these appearances that this plant contains two distinct kinds of pith tissue, differing in duration and probably in function, I obtained, for comparison, specimens of living plants of this and allied families. In some of these, and especially in a species labelled "*Ficus imperialis*," from Jamaica, I found the same structure; and in the young branches, before the central part of the pith was broken up, it was evident that the tissue was of two distinct kinds: one forming the outer coating and transverse partitions opposite the insertions of the leaves, and retaining its vitality for several years at least; the other, occupying the intervening spaces or internodes, of looser texture, speedily drying up, and ultimately disappearing.

The trunks above noticed are of rapid growth, and have large leaves; and it is probable that the more permanent pith tissue of the medullary lining and partitions serves to equalize the distribution of the juices of the stem, which might otherwise be endangered by the tearing of the ordinary pith in the rapid elongation of the internodes. A similar structure has evidently existed in the Coal formation conifers of the genus Dadoxylon, and possibly they also were of rapid growth and furnished with very large or abundant leaves.

Applying the facts above stated to the different varieties or species of Sternbergia, we must, in the first place, connect with these fossils such plants as the *Pinites medullaris* of Witham. I have not seen a longitudinal section of this fossil, but should expect it to present a transverse structure of the Sternbergia type. The first specimen described by Professor Williamson represents a second variety, in which the transverse structure is developed in the central part of the pith, but not at the sides. In my Pictou specimen the pith has wholly disappeared, with the exception of the denser outer coating and transverse plates. All these are distinctly coniferous, and the differences that appear may be due merely to age, or more or less rapid growth.

Other specimens of Sternbergia want the internal partitions, which may, however, have been removed by decay; and these often retain very imperfect traces, or none, of the investing wood. In the case of those which retain any portion of the wood sufficient to render probable their coniferous character, the surface markings are similar in character to those of my Pictou specimen, but often vary greatly in their dimensions, some having fine transverse wrinkles, others having these wide and coarse. Of those specimens which retain no wood, but only a thin coaly investment representing the outer pith, many cannot be distinguished by their superficial markings from those that

are known to be coniferous, and they occasionally afford evidence that we must not attach too much importance to the character of their markings. A very instructive specimen of this kind from Ohio, with which I have been favoured by Professor Newberry, has in a portion of its thicker end very fine transverse wrinkles, and in the remainder of the specimen much coarser wrinkles. This difference marks, perhaps, the various rates of growth in successive seasons, or the change of the character of the pith in older portions of the stem.

The state of preservation of the Sternbergia casts, in reference to the woody matter which surrounded them, presents, in a geological point of view, many interesting features. Professor Williamson's specimen I suppose to be unique, in its showing all the tissues of the branch or trunk in a good state of preservation. More frequently, only fragments of the wood remain, in such a condition as to evidence an advanced state of decay, while the bark-like medullary lining remains. In other specimens, the coaly coating investing the cast sends forth flat expansions on either side, as if the Sternbergia had been the midrib of a long thick leaf. This appearance, at one time very perplexing to me, I suppose to result from the entire removal of the wood by decay, and the flattening of the bark, so that a perfectly flattened specimen may be all that remains of a coniferous branch nearly two inches in diameter. A still greater amount of decay of woody tissue is evidenced by those Sternbergia casts which are thinly coated with structureless coal. These must, in many cases, represent trunks and branches which have lost their bark and wood by decay; while the tough cork-like chambered pith drifted away to be imbedded in a separate state. This might readily happen with the pith of Cecropia; and perhaps that of these coniferous trees may have been more durable; while the wood, like the sap-wood of many modern pines, may have been susceptible of rapid decay, and liable, when exposed to alternate moisture and dryness, to break up into those rectangular blocks which are seen in the decaying trunks of modern conifers, and are so abundantly scattered over the surfaces of coal and its associated beds in the form of mineral charcoal.

Some specimens of Sternbergia appear to show that they have existed in the interior of trunks of considerable size. I have observed one at the South Joggins, which appears to show the remains of a tree a foot in diameter, now flattened and converted into coal, but retaining a distinct cast of a wrinkled Sternbergia pith. (Fig. 160, E.)

Are we to infer from these facts that the wood of the trees of the genus Dadoxylon was necessarily of a lax and perishable texture? Its structure, and the occurrence of the heart-wood of huge trunks of

similar character in a perfectly mineralized condition, would lead to a different conclusion; and I suspect that we should rather regard the mode of occurrence of Sternbergia as a caution against the too general inference, from the state of preservation of trees of the Coal formation, that their tissues were very destructible, and that the beds of coal must consist of such perishable materials. The coniferous character of the Sternbergiæ, in connexion with their state of preservation, seems to strengthen a conclusion at which I have been arriving from microscopic and field examinations of the coal and carbonaceous shales, that the thickest beds of coal, at least in Eastern America, consist in great part of the flattened bark of coniferous, sigillarioid, and lepidodendroid trees, the wood of which has perished by slow decay, or appears only in the state of fragments and films of mineral charcoal. This subject, however, will be introduced in the next section of this chapter. In my researches in microscopic coal structures, I have also ascertained that some Sternbergiæ are pith cylinders of Sigillariæ. (Fig. 161, M).

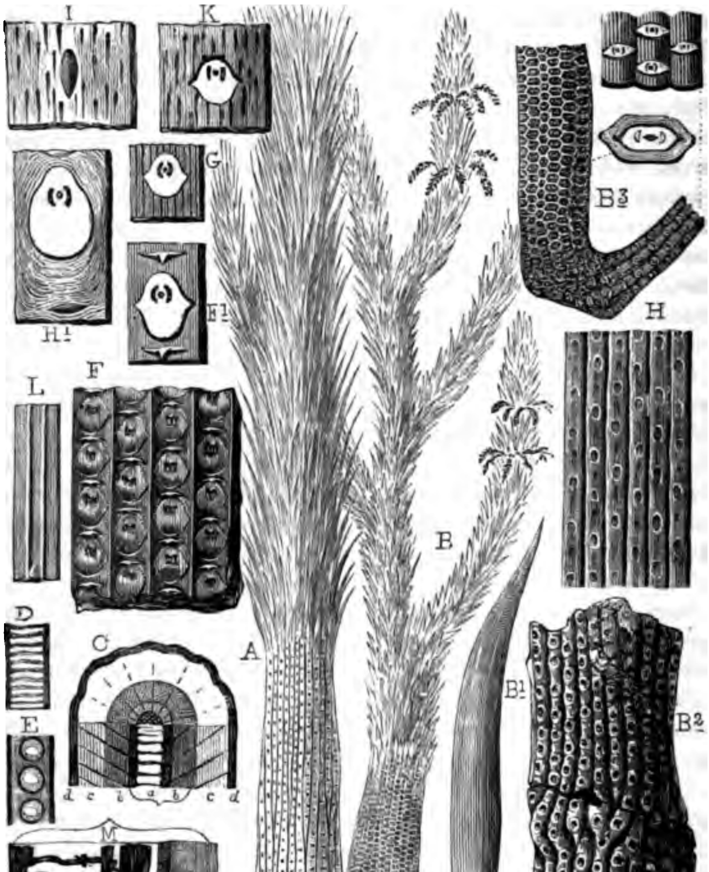
The most abundant locality of Sternbergia with which I am acquainted occurs in the neighbourhood of the town of Pictou, immediately below the bed of erect calamites described in the Journal of the Geological Society (vol. vii., p. 194). The fossils are found in interrupted beds of very coarse sandstone, with calcareous concretions, imbedded in a thick reddish brown sandstone. These gray patches are full of well-preserved Calamites, which have either grown upon them, or have been drifted in clumps with their roots entire. The appearances suggest the idea of patches of gray sand rising from a bottom of red mud, with clumps of growing Calamites which arrested quantities of drift plants, consisting principally of Sternbergia and fragments of much decayed wood and bark, now in the state of coaly matter, too much penetrated by iron pyrites to show its structure distinctly. We thus probably have the fresh growing Calamites entombed along with the debris of the old decaying conifers of some neighbouring shore; furnishing an illustration of the truth, that the most ephemeral and perishable forms may be fossilized and preserved contemporaneously with the decay of the most durable tissues. The rush of a single summer may be preserved with its minutest striæ unharmed, when the giant pine of centuries has crumbled into dust or disappeared.

2. *Sigillariaceæ or Sigillarioid Trees.*

1. *Genus Sigillaria.*—The Sigillariæ, so named from the seal-like scars of fallen leaves stamped on their bark, were the most important of all the trees of the coal-swamps, and those which contributed most

largely to the production of coal. Let us take as an example of them a species very common at the Joggins, and which I have named *S. Brownii*, in honour of my friend, Mr R. Brown of Sydney. Imagine a tall cylindrical trunk spreading at the base, and marked by perpendicular rounded ribs giving it the appearance of a clustered or fluted column. These ribs are marked by rows of spots or pits left by fallen leaves, and toward the base they disappear, and the bark becomes rough and uneven, but still retains obscure indications of the leaf-scars, widened transversely by the expansion of the stem. At the base the trunk spreads into roots, but with a regular bifurcation quite unexampled in modern trees, and the thick cylindrical roots are marked with round sunken pits or areoles, from which spread long cylindrical rootlets. These roots are the so-called *Stigmariæ*, at one time regarded as independent plants, and, as the reader may have already observed, remarkable for their constant presence in the underclays of the coal-beds. Casting our eyes upward, we find the pillar-like trunk, either quite simple or spreading by regular bifurcation into a few thick branches, covered with long narrow leaves looking like grass, or, more exactly, like pine leaves greatly increased in size, or, more exactly still, like single leaflets of the leaves of Cycads. Near the top, if the plant were in fruit, we might observe long catkins of obscure flowers or strings of large nut-like seeds, borne in rings or whorls encircling the stem. If we could apply the woodman's axe to a *Sigillaria*, we should find it very different in structure from that of our ordinary trees, but not unlike that of the Cycads, or false sago-plants of the tropics. A lumber-man would probably regard it as a tree nearly all bark, with only a slender core of wood in the middle; and, botanically, he would be very near the truth. The outer rind or bark of the tree was very hard. Within this was a very thick inner bark, partly composed of a soft corky cellular tissue, and partly of long tough fibrous cells like those of the bark of the cedar. This occupied the greater part of the stem even in old trees four or five feet in diameter. Within this we would find a comparatively small cylinder of wood, not unlike pine in appearance, and even in its microscopic structure; and in the centre a large pith, often divided, by the tension caused in the growth of the stem, into a series of horizontal tables or partitions. Such a stem would have been of little use for timber, and of comparatively small strength. Still the central axis of wood gave it rigidity, the surrounding fibres, like cordage, gave the axis support, and the outer shell of hard bark must have contributed very materially to the strength of the whole. Growing as these trees did in swampy flats close together, and the bark of which they were chiefly composed being less

Fig. 161.—*Sigillariæ.*



A, *Sigillaria Brownii*, restored. For other illustrations of this species, see Fig. 30.
B, *S. elegans*, restored.
B1, Leaf of S. elegans.
B2, Portion of decorticated stem, showing one of the transverse bands of fruit-scars.
B3, Portion of stem and branch reduced, and scars nat. size.
C, Cross section of Sigillaria Brownii (?), reduced, and portion at (M) natural size. (*a*) Sternbergia pith, (b^1) Inner cylinder of scalariform vessels. (b^2) Outer cylinder of discigerous cells, with medullary rays and bundles of scalariform vessels going to the leaves at (b^3). (*c*) Inner bark. (*d*) Outer bark.
D, Scalariform vessel magnified.
E, Discigerous woody fibre, magnified.
F, *Sigillaria Bretonensis*, ⅓. (f^1) Areole, n. size.
G, *S. striata*, nat. size.
H, *S. eminens*, reduced. (H1) areole, half n. size.
I, *S. catenoides*, half nat. size.
K, *S. planicosta*, half nat. size.
L, Portion of leaf of *S. scutellata*.

susceptible of rapid decay than most kinds of wood, and too impervious to fluids to be readily penetrated by mineral matter, they were admirably fitted for the production of the raw material of coal.

I have endeavoured to represent the structures above referred to in Fig. 161.

The species to which I have referred was only one of many more or less resembling it, but differing in details; and according to these special differences, they may be arranged in the following genera, which may, however, be much modified by the progress of discovery. Opposite each genus I have given the species representing it in Nova Scotia.

(1.) FAVULARIA, *Sternberg* . . .	Sigillaria elegans, *Brongn.*
	—— tessellata, *Brongn.*
	—— Bretonensis, *Dawson.*
(2.) RHYTIDOLEPIS, *Sternberg* . .	—— scutellata, *Brongn.*
	—— Schlotheimiana, *Brongn.*
	—— Saullii, *Brongn.*
	—— Dournaisii, *Brongn.*
	—— Knorrii, *Brongn.*
	—— pachyderma, *Brongn.*
	—— flexuosa, *L. & H.?*
	—— elongata, *Brongn.*
(3.) SIGILLARIA, *Brongn.*	—— reniformis, *Brongn.*
	—— Brownii, *Dawson.*
	—— lævigata, *Brongn.*
	—— planicosta, *Dawson.*
	—— catenoides, *Dawson.*
	—— striata, *Dawson.*
	—— eminens, *Dawson.*
(4.) CLATHRARIA, *Brongn.*	—— Menardi, *Brongn.*
(5.) LEIODERMA, *Goldenb.* . . . . (Asolanus, *Wood*).	—— Sydnensis, *Dawson.*
(6.) SYRINGODENDRON, *Sternb.* . .	—— organum, *L. & H.*

Of these, seven are probably new species, and the remainder can be identified with reasonable certainty with European species. The differences in the markings in different parts of the same tree are, however, so great, that I regard the greater part of the recognised species of *Sigillariæ* as merely provisional. Even the generic limits may be overpassed when species are determined from hand specimens. A fragment of the base of an old trunk of *Sigillaria* proper would necessarily be placed in the genus *Leioderma*, and a young branch of

Favularia has all the characters of the genus *Clathraria*. It is, however, absolutely necessary to make some attempt at generic distinction among the diverse forms included in the genus *Sigillaria;* otherwise it will be impossible to reconcile the conflicting statements of authors as to the dimensions, habit of growth, foliage, roots, and fructification of these singular plants;—such statements usually applying to one or more of the subordinate generic types. I shall therefore notice separately, and with especial reference to their function in the production of coal, the several generic or subgeneric forms, beginning with that which I regard as the most important—namely, *Sigillaria* proper, of which, in Nova Scotia, I regard the species which I have named *S. Brownii* as the type. Other species are represented in Figs. 161, B to K.

In the restricted genus *Sigillaria* the ribs are strongly developed, except at the base of the stem; they are usually much broader than the oval or elliptical tripunctate areoles, and are striated longitudinally. The woody axis has both discigerous and scalariform tissues, arranged in wedges, with medullary rays as in exogens;* the pith is transversely partitioned in the manner of *Sternbergia;* and the inner bark contains great quantities of long and apparently very durable fibres, which I have, in my descriptions of the structures in the coal, named "bast tissue." The outer bark was usually thick, of dense and almost indestructible cellular tissue. The trunk when old lost its regular ribs and scars, owing to expansion, and became furrowed like that of an old exogenous tree. The roots were *Stigmariæ* of the type of *S. ficoides*. (Fig. 30, *d*, p. 180.) I have not seen the leaves or fruits attached; but, from the association observed, I believe that the former were long, narrow, rigid, and two-or-three-nerved (*Cyperites*), and that the latter were *Trigonocarpa*, borne in racemes on the upper part of the stem. These trees attained to a great size. I have seen one trunk four feet in diameter, and specimens of two feet or more in diameter are common: some of these trunks have been traced for thirty or forty feet without branching. The greater number of the erect stumps preserved at the Joggins appear to belong to this genus, which also seems to have contributed very largely to the formation of coal. Judging from the paucity of their foliage, the density of their tissues, and the strong structural resemblance of their stems and roots to those of Cycads, I believe that their rate of growth must have been very slow.

The genus *Rhytidolepis*, in which the areoles are large, hexagonal, and tripunctate, and the ribs narrow and often transversely striate, ranks as a coal-producer next to *Sigillaria* proper, and is equally

* Quart. Journ. Geol. Soc., paper on Structures of Coal.

abundant in the Coal measures. These trees seem to have been of smaller size and feebler structure than the last mentioned, and are less frequently found in the erect position; but they are very abundant on the roofs of the coal beds. Judging from such specimens as I have seen, their roots were less distinctly stigmarioid than in the last genus, though this appearance may arise from difference of preservation. Their leaves were of the same type as in the last genus; and their stems bear rings of irregular scars, which may mark stages of growth, or the production of slender racemes of fruit in a verticillate manner. The woody axis of the stems of this genus was composed of scalariform and coarsely porous tissues, much like those of modern Cycads. I figure, as an illustration of the genus, a fragment of *S. Bretonensis* (Fig. 161, F).

The genus *Favularia* is represented in Nova Scotia principally by the typical species *S. elegans* of Brongniart. The admirable investigations of the structure of the stem of this species by Brongniart, with the further illustrations given by Corda, Hooker, and Goldenberg, still afford the best general views of the structure of *Sigillariæ* which we possess. It is to be observed, however, that Brongniart's specimen was a young stem or a branch, and that it affords a very imperfect idea of the development of discigerous and bast tissues in the full-grown stems of *Sigillaria* proper. The trees of this genus appear to have been of small growth; and they branched in the manner of *Lepidodendron*, the smaller branches being quite destitute of ribs, and with the areoles elliptical and spirally disposed. The stems show joints or rings of peculiar scars at intervals, as in the last genus. The leaves differ from those of the other genera, being broad and with numerous slender parallel veins, almost in the manner of *Cordaites* (Fig. 161, B^1).

The genus *Clathraria* is evidently closely allied to the above, and is possibly founded on branches of trees of the genus *Favularia*. It is a rare form in Nova Scotia.

Of the genus *Leioderma* or *Asolanus* I know but one species, independently of those specimens of old trunks of the ordinary *Sigillaria* in which the ribs have disappeared. My species, *S. Sydenensis*, is founded on specimens collected by Mr Brown at Sydney, Cape Breton, which are especially remarkable for the curious modification which they present of the Stigmarian root. The specimens described by Mr Brown under the name of *S. alternans*,* and which have been copied by Geinitz and Goldenberg, belong, I believe, to this species.

* Quart. Journ. Geol. Soc., vol. v. p. 354. *et seq.* See also my paper on "Conditions of Accumulation of Coal," Quart. Journ. Geol. Soc., vol. xxii. p. 147, and Pl. vii, Figs. 28, *a*, *b*, *c*.

On the genus *Syringodendron* of Sternberg I have no observations to make. I have seen only fragments of stems; and these seem to be very rare.

I include under *Sigillariæ* the remarkable fossils known as *Stigmaria*, being fully convinced that all the varieties of these plants known to me are merely roots of *Sigillaria;* I have verified this fact in a great many instances, in addition to those so well described by Mr Binney and Mr Brown. The different varieties or species of *Stigmaria* are no doubt characteristic of different species of *Sigillaria*, though in very few cases has it proved possible to ascertain the varieties proper to the particular species of stem. The old view, that the *Stigmariæ* were independent aquatic plants, still apparently maintained by Goldenberg and some other palæobotanists, evidently proceeds from imperfect information. Independently of their ascertained connexion with *Sigillaria*, the organs attached to the branches are not leaves, but rootlets. This was made evident long ago by the microscopic sections published by Goeppert, and I have ascertained that the structure is quite similar to that of the thick fleshy rootlets of *Cycas*. The lumps or tubercles on these roots have been mistaken for fructification; and the rounded tops of stumps, truncated by the falling in of the bark or the compression of the empty shell left by the decay of the wood, have been mistaken for the natural termination of the stem.* The only question remaining in regard to these organs is that of their precise morphological place. Their large pith and regular areoles render them unlike true roots; and hence Lesquereux has proposed to regard them as *rhizomes*. But they certainly radiate from a central stem, and are not known to produce any true buds or secondary stems. In short, while their function is that of roots, they may be regarded, in a morphological point of view, as a peculiar sort of underground branches. They all ramify very regularly in a dichotomous manner, and, as Mr Brown has shown, in some species at least, give off conical tap-roots from their underside.

In all the *Stigmariæ* exhibiting structure which I have examined, the axis shows only scalariform vessels. Corda, however, figures a species with wood-cells, or vessels with numerous pores, quite like those found in the stems of *Sigillaria* proper; and, as Hooker has pointed out, the arrangement of the tissues in *Stigmaria* is similar to that in *Sigillaria*. After making due allowance for differences of preservation, I have been able to recognise eleven species or forms

* For examples of the manner in which a natural termination may be simulated by the collapse of bark or by constriction owing to lateral pressure, see my papers, Quart. Journ. Geol. Soc., vol. x. p. 35, and vol. vii. p. 194.

of *Stigmaria* in Nova Scotia, corresponding, as I believe, to as many species of *Sigillaria*.* At the Joggins, *Stigmariæ* are more abundant than any other fossil plants. This arises from their preservation in the numerous fossil soils or *Stigmaria* underclays. Their bark, and mineral charcoal derived from their axes, also abound throughout the thickness of the coal beds, indicating the continued growth of *Sigillaria* in the accumulation of the coal.

Our knowledge of the fructification of *Sigillaria* is as yet of a very uncertain character. I am aware that Goldenberg has assigned to these plants leafy strobiles containing spore-capsules: but I do not think the evidence which he adduces conclusive as to their connexion with *Sigillaria;* and the organs themselves are so precisely similar to the strobiles of *Lepidophloios*, that I suspect they must belong to that or some allied genus. The leaves, also, with which they are associated in one of Goldenberg's figures seem more like those of *Lepidophloios* than those of *Sigillaria*. If, however, these are really the organs of fructification of any species of *Sigillaria*, I think it will be found that we have included in this genus, as in the old genus *Calamites*, two distinct groups of plants, one cryptogamous, and the other phænogamous, or else that male strobiles bearing pollen have been mistaken for spore-bearing organs.

I cannot pretend that I have found the fruit of *Sigillaria* attached to the parent stem; but I think that a reasonable probability can be established that some at least of the fruits included, somewhat vaguely, by authors under the names of *Trigonocarpum* and *Rhabdocarpus*, were really fruits of *Sigillaria*. These fruits are excessively abundant and of many species, and they occur not only in the sandstones, but in the fine shales and coals and in the interior of erect trees, showing that they were produced in the coal-swamps. The structures of these fruits show that they are phænogamous and probably gymnospermous. Now the only plants known to us in the Coal formation, whose structures entitle them to this rank, are the *Conifers*, *Sigillariæ*, and *Calamodendra*. All the others were in structure allied to cryptogams, and the fructification of most of them is known. But the Conifers were too infrequent in the Carboniferous swamps to have afforded numerous species of *Carpolites;* and, as I shall presently show, the *Calamodendra* were very closely allied to *Sigillariæ*, if not members of that family. Unless, therefore, these fruits belonged to *Sigillaria*, they must have been produced by some other trees of the coal-swamps, which, though very abundant and of numerous species, are as yet quite unknown to us. Some of the *Trigonocarpa* have been claimed

* See Paper on Accumulation of Coal, Journ. Geol. Soc., vol. xxii.

for Conifers, and their resemblance to the fruits of *Salisburya* gives countenance to this claim; but the Conifers of the Coal period are much too few to afford more than a fraction of the species. One species of *Rhabdocarpus* has been attributed by Geinitz to the genus *Nœggerathia;* but the leaves which he assigns to it are very like those of *Sigillaria elegans*, and may belong to some allied species. With regard to the mode of attachment of these fruits, I have shown that one species, *Trigonocarpum racemosum* of the Devonian strata,* was borne on a rhachis in the manner of a loose spike, and I am convinced that some of the groups of inflorescence named *Antholithes* are simply young *Rhabdocarpi* or *Trigonocarpa* borne in a pinnate manner on a broad rhachis and subtended by a few scales. Such spikes may be regarded as corresponding to a leaf with fruits borne on the edges, in the manner of the female flower of *Cycas;* and I believe with Goldenberg that these were borne in verticils at intervals on the stem. In this case it is possible that the strobiles described by that author may be male organs of fructification containing, not spores, but pollen. In conclusion, I would observe that I would not doubt the possibility that some of the fruits known as *Cardiocarpa* may have belonged to sigillarioid trees. I am aware that some so-called *Cardiocarpa* are spore-cases of *Lepidodendron;* but there are others which are manifestly winged nutlets allied to *Trigonocarpum*, and which must have belonged to phænogams. It would perhaps be unwise to insist very strongly on deductions from what may be called circumstantial evidence as to the nature of the fruit of *Sigillaria;* but the indications pointing to the conclusions above stated are so numerous that I have much confidence that they will be vindicated by complete specimens, should these be obtained.

All of the Joggins coals, except a few shaly beds, afford unequivocal evidence of *Stigmaria* in their underclays; and it was obviously the normal mode of growth of a coal-bed, that, a more or less damp soil being provided, a forest of *Sigillaria* should overspread this, and that the Stigmarian roots, the trunks of fallen *Sigillariæ*, their leaves and fruits, and the smaller plants which grew in their shade, should accumulate in a bed of vegetable matter to be subsequently converted into coal—the bark of *Sigillaria* and allied plants affording "bright coal," the wood and bast tissues mineral charcoal, and the herbaceous matter and mould dull coal. The evidence of this afforded by microscopic structure I have endeavoured to illustrate in a former paper.†

The process did not commence, as some have supposed, by the

* "Flora of the Devonian Period," Quart. Journ. Geol. Soc., vol. viii. p. 324.

† "On the Structures in Coal," Quart. Journ. Geol. Soc. 1859.

growth of *Stigmaria* in ponds or lakes. It was indeed precisely the reverse of this, the *Sigillaria* growing in a soil more or less swampy but not submerged, and the formation of coal being at last arrested by submergence. I infer this from the circumstance that remains of Cyprids, Fishes, and other aquatic animals, are rarely found in the underclays and lower parts of the coal-beds, but very frequently in the roofs, while it is not unusual to find mineral charcoal more abundant in the lower layers of the coal. For the formation of a bed of coal, the sinking and subsequent burial of an area previously dry seems to have been required. There are a few cases at the Joggins where *Calamites* and even *Sigillariæ* seem to have grown on areas liable to frequent inundation; but in these cases coal did not accumulate. The non-laminated, slicken-sided and bleached condition of most of the underclays indicates soils of considerable permanence.

In regard to beds destitute of Stigmarian underclays, the very few cases of this kind apply only to shaly coals filled with drifted leaves, or to accumulations of vegetable mud capable of conversion into impure coal. The origin of these beds is the same with that of the carbonaceous shales and bituminous limestones already referred to. It will be observed in the section that in a few cases such beds have become sufficiently dry to constitute underclays, and that conditions of this kind have sometimes alternated with those favourable to the formation of true coal.

There are some beds at the Joggins, holding erect trees *in situ*, which show that *Sigillariæ* sometimes grew singly or in scattered clumps, either alone or amidst brakes of *Calamites*. In other instances they must have grown close together, and with a dense undergrowth of ferns and *Cordaites*, forming an almost impenetrable mass of vegetation.

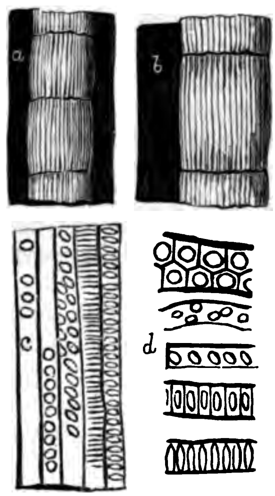
From the structure of *Sigillariæ* I infer that, like Cycads, they accumulated large quantities of starch, to be expended at intervals in more rapid growth, or in the production of abundant fructification. I adhere to the belief expressed in previous papers that Brongniart is correct in regarding the *Sigillariæ* as botanically allied to the *Cycadaceæ*, and I have recently more fully satisfied myself on this point by comparisons of their tissues with those of *Cycas revoluta*. It is probable, however, that when better known they will be found to have a wider range of structure and affinities than we now suppose.

There are some reasons for believing that the trees described by Corda under the names of *Diploxylon*, *Myelopithys*, and *Heterangium*, and also the *Anabathra* of Witham, are *Sigillariæ*. Much of the tissue

described by Goeppert as *Araucarites carbonarius* is probably also Sigillarian.

2. *Calamodendron* or *Calamitea*.—These plants are much less known than the proper Sigillarias, and it is perhaps doubtful if they should not form a separate family. In the meantime I place them here, simply because they seem to approach more nearly to *Sigillariæ* than any other plants in their structure. They were of less massive growth than *Sigillariæ*, being rarely more than a few inches in diameter; they had stems fluted lengthwise like *Sigillaria*, but more distinctly divided into nodes or joints by the scars of branches which were borne in whorls, and carried their narrow, slender leaves. In their habit of

Fig. 162.—*Calamodendron*.



(*a*, *b*) Casts of axis in sandstone, with woody envelope, reduced.
(*c*, *d*) Woody tissue, highly magnified.

growth they thus resembled the pine tribe, and they seem to have had a larger amount of true wood in their stems than was the case with *Sigillaria*. This cylinder of wood contained a thick pith, which was constricted at intervals into joints, and had also a longitudinal striation on the outside; and as this pith from its ready decay admitted sand into the interior of the stem, while the wood was entire or in process of conversion into coal, we often have a stem of *Calamodendron* represented merely by a cast of the pith in stone. In this case the pith cylinder may be easily mistaken for a plant of the genus *Calamites*, which, as we shall immediately find, was quite a different thing. I

believe that the statements often found in geological books to the effect that the *Calamites* were smooth externally, and that the supposed jointed stems are only casts of the pith, are true of *Calamodendron* only, and proceed from confounding that genus with *Calamites*.

A *Calamodendron* as usually seen is a striated cast with frequent cross lines or joints; but when the whole stem is preserved, it is seen that this cast represents merely an internal pith-cylinder, surrounded by a woody cylinder composed in part of scalariform or reticulated vessels, and in part of wood-cells with one row of large pores on each side. External to the wood was a cellular bark, and the outer surface seems to have been simply ribbed in the manner of *Sigillaria*. It so happens that the internal cast of the pith of *Calamodendron*, which is really of the nature of a *Sternbergia*, so closely resembles the external appearance of the true *Calamites* as to be constantly mistaken for them. Most of these pith-cylinders of *Calamodendron* have been grouped in the species *Calamites approximatus*; but that species, as understood by some authors, appears also to include true *Calamites*,* which, however, when well preserved, can always be distinguished by the scars of the leaves or branchlets which were attached to the nodes.

Calamodendron would seem, from its structure, to have been closely allied to *Sigillaria*, though, according to Unger, the tissues were differently arranged, and the woody cylinder must have been much thicker in proportion.

The tissues of *Calamodendron* are by no means infrequent in the coal, and casts of the pith are common in the sandstones; but its foliage and fruit are unknown. They probably resembled those of *Sigillaria*.

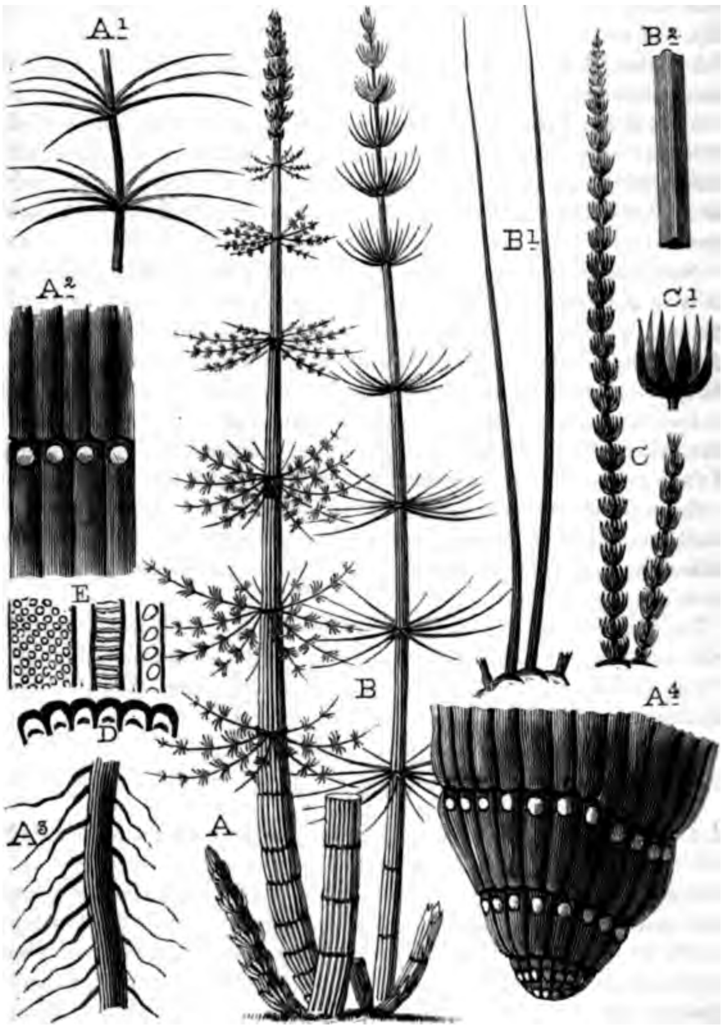
CLASS OF CRYPTOGAMS.

1. *Equisetaceæ*.

1. *Calamites*.—These curious plants are by no means to be confounded with those last noticed. Their stems were slender, ribbed and jointed externally, and from the joints there proceeded, in some of the species, long, narrow, simple branchlets; and, in others, branches bearing whorls of small branchlets or rudimentary leaves. The stem was hollow, with thin transverse floors or diaphragms at the joints, and it had no true wood and bark, but only a thin external shell of fibres and scalariform vessels. The *Calamites* grew in dense brakes on the sandy and muddy flats, subject to inundation, or perhaps even in the water, and they had the power of budding out from the base of the stem, so as to form clumps of plants, and also of securing their foot-

* See Geinitz, "Steinkohlen formation in Sachsen."

Fig. 163.—*Calamites.*



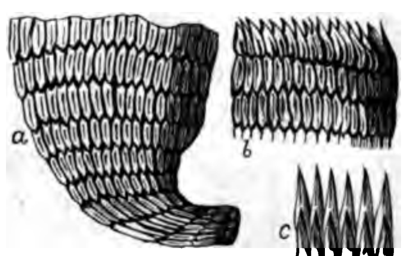
A, Calamites Suckovii, restored.
A1, Foliage.
A2, Ribs and scars.
A3, Roots.
A4, Base of stem.
B, Calamites Cistii, restored.
B1, Leaves.
B2, Leaf enlarged.
C, Leaves of C. nodosus.
C1, Whorl enlarged.
D, Structure of stem.
E, Vessels magnified.

hold by numerous cord-like roots, proceeding from various heights on the lower part of the stem.* The fruit was a long cone or spike, bearing spore cases under scales. The *Calamites* were evidently close relations of the modern horse-tails or scouring-rushes, differing principally in their great size, the want of sheaths at the joints, and the details of the fructification (Fig. 163).

Most of the points above stated, as well as the conical form of the lower end of these *Calamites*, which budded out from others, were explained by me in the "Journal of the Geological Society" as far back as 1849, yet the most ridiculous errors are still current in elementary books.

Nine species of true *Calamites* have been recognised in Nova Scotia, of which seven occur at the Joggins, the most abundant being *C. Suckovii* and *C. Cistii*. As just observed, the *Calamites* grew in dense brakes on sandy and muddy flats, in the manner of modern *Equisetaceæ*, and produced at their nodes either verticillate simple linear leaves, as in *C. Cistii*, or verticillate branchlets with pinnate or verticillate leaflets, as in *C. Suckovii* and *C. nodosus*. The *Calamites* do not seem to have contributed much to the growth of coal, though their remains are not infrequent in it. The soils in which they most frequently grew were apparently too wet and liable to inundation and silting up to be favourable to coal-accumulation.

Fig. 164.—*Equisetites Curta.*



(*a*, *b*) Portions of stem. (*c*) Sheaths.

2. *Equisetites.*—This genus includes a few plants which, like the modern horse-tails, had sheaths at the joints. One species only has been found in Nova Scotia, and little is known of this except the form of the lower part of the stem (Fig. 164).

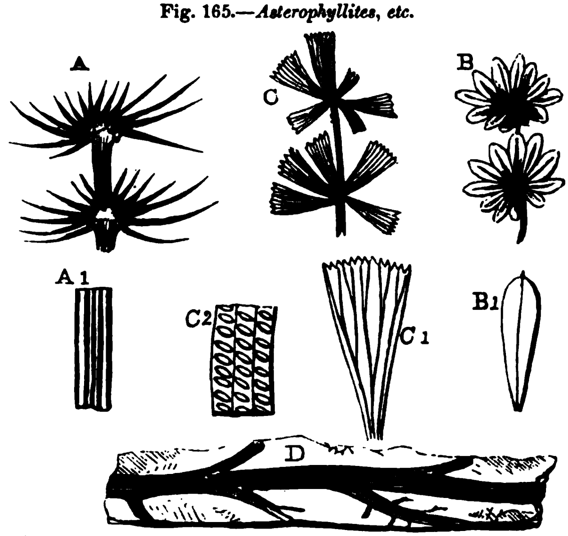
3. *Asterophyllites.*—These beautiful plants do not appear to have been of large size, and, like the other members of this family, probably

* Quart. Journ. of Geol. Soc., vol. x. p. 34.

grew in wet or inundated ground. They had ribbed and jointed stems like the *Calamites*, but with a stout internal woody cylinder, in which respect they resembled miniature *Calamodendra*. From the joints proceeded whorls of leaves, or of branchlets, bearing leaves which differed from those of *Calamites* in their having a distinct middle rib or vein. The fructification consisted of long slender cones or spikes, having whorls of scales among the spore cases. Some authors speak of *Asterophyllites* as only branches and leaves of *Calamites;* but though at first sight the resemblance is great, a close inspection shows that the leaves of *Asterophyllites* have a true midrib, which is wanting in *Calamites*. Five species of *Asterophyllites* have been found in Nova Scotia and New Brunswick (Fig. 165, A).

4. *Annularia*.—It is questionable whether these plants should be separated from *Asterophyllites*. The distinction is that they produce branches in pairs, and that their whorls of leaves are one-sided, and usually broader than those of *Asterophyllites*, and united into a ring at their insertion on the stem. One little species is very common in Nova Scotia, and a larger one hitherto included in *Asterophyllites* is also abundant (Fig. 165, B).

Fig. 165.—*Asterophyllites, etc.*



A, Asterophyllites trinerne. (A^1) Leaf enlarged.
B, Annularia sphenophylloides. (B^1) Leaf enlarged.
C, Sphenophyllum erosum. (C^1) Leaflet enlarged. (C^2) Scalariform vessel.
D, Pinnularia ramosissima.

5. *Sphenophyllum*.—This is one of the prettiest plants of the coal; its little whorls of wedge-shaped leaves, often scattered thickly over

the surfaces of the shales, resembling flowers. Its stems were very slender, but branching copiously, and bearing wedge-shaped leaves often toothed at the edges, and veined in the manner of fern leaves. The spores were borne on small spikes like those of *Asterophyllites*. Five species have been recognised in the Acadian Coal-fields. I am not aware that this and the two preceding genera contributed to any great extent to the accumulation of coal; but as their tissues were scalariform, similar to those of ferns, it would not be easy to recognise them. A beautiful specimen of *Sphenophyllum emarginatum* from New Brunswick, in the collection of Sir W. E. Logan, has enabled me to ascertain that its stem had a simple axis of one bundle of reticulato-scalariform vessels, like those of *Tmesipteris* as figured by Brongniart. These curious plants were no doubt cryptogamous, having a habit of growth like that of *Equisetaceæ*, leaves like those of ferns or *Marsiliaceæ*, and fructification and structure like those of *Lycopodiaceæ* (Fig. 165, C).

6. *Pinnularia*.—These are slender roots, or stems branching in a pinnate manner, and somewhat irregularly. They are very abundant in the coal shales, and were probably not independent plants, but aquatic roots belonging to some of the plants last mentioned. The probability of this is farther increased by their resemblance in miniature to the roots of *Calamites*. They are always flattened, but seem originally to have been round, with a slender thread-like axis of scalariform vessels, enclosed in a soft smooth cellular bark (Fig. 165, D).

2. *Filices or Ferns*.

The ferns or brackens are still very abundant in the forests of Acadia, but do not constitute nearly so prominent a part of the flora as in the days of the Coal formation, when the species were vastly more numerous in proportion to other plants, and when there were tree ferns similar to those of the present tropics and southern hemisphere, as well as the smaller herbaceous species. The fronds of fossil ferns are often well preserved, but we usually obtain them only in fragments and destitute of the fructification, which is the most distinctive character in living ferns. Hence we are obliged to arrange the fossil ferns in an arbitrary manner; the stems, when found, by themselves and the fronds by themselves, and the latter in groups based on venation and other comparatively unimportant characters, rather than on fructification. The classification thus formed is altogether provisional, and when our knowledge of the subject shall become more complete, must give way to one of a more natural character. In the

Fig 166.—*Ferns of the Middle Coal Formation.*

A, Odontopteris subcuneata (after Bunbury).
B, Neuropteris cordata do.
C, Alethopteris lonchitica.
D, Dictyopteris obliqua (after Bunbury).
E, Phyllopteris antiqua, mag. (E^1) Nat. size.
F, Neuropteris cyclopteroides.
(For other species see Figs. 69 to 72.)

meantime the principal genera, of which representatives have been found in Acadia, are the following (Figs. 166, 167, and Figs. 69 to 72):—

1. *Cyclopteris*, Brongn.—Leaflets more or less rounded, or wedge-shaped, without midrib, the nerves spreading from the point of attachment. This group includes a great variety of fronds evidently of different genera, were their fructification known; and some of them probably portions of fronds, the other parts of which may be in the next genus.

2. *Neuropteris*, Brongn.—Fronds pinnated, and with the leaflets narrowed at the base; midrib often not distinct, and disappearing toward the apex. Nervures equal, and rising at an acute angle. Ferns of this type are among the most abundant in the Coal formation.

3. *Odontopteris*, Brongn.—In these the frond is pinnate, and the leaflets are attached by their whole base, with the nerves either proceeding wholly from the base, or in part from an indistinct midrib, which soon divides into nervures.

4. *Dictyopteris*, Gutbier.—This is a beautiful style of fern, with leaflets resembling those of *Neuropteris*, but the veins arranged in a network of oval spaces. Only one species is known in our Coal formation.

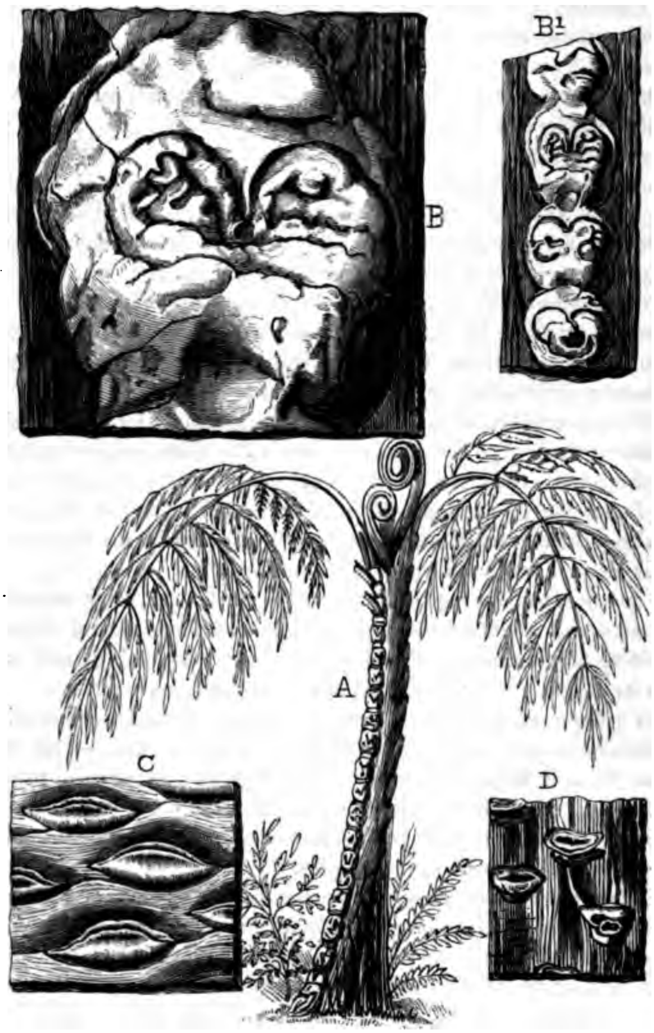
5. *Lonchopteris*, Brongn.—Ferns with netted veins like the above, but with a distinct midrib, and the leaflets attached by the whole base. Of this also we can boast but a single species.

6. *Sphenopteris*, Brongn.—These are elegant ferns, very numerous in species, and most difficult to discriminate. Their most distinctive characters are leaflets narrowed at the base, often lobed, and with nervures dividing in a pinnate manner from the base.

7. *Phyllopteris*, Brongn.—These are pinnate, with long lanceolate pinnules, having a strong and well defined midrib, and nerves proceeding from it very obliquely, and dividing as they proceed toward the margin. The ferns of this genus are for the most part found in formations more recent than the Carboniferous; but I have referred to it, with some doubt, one of our species.

8. *Alethopteris*, Brongn.—This genus includes many of the most common Coal formation ferns, especially the ubiquitous *A. lonchitica*, which seems to have been the common brake of the Coal formation, corresponding to *Pteris aquilina* in modern Europe and America. These are brake-like ferns, pinnate, with leaflets often long and narrow, decurrent on the petiole, adherent by their whole base, and united at base to each other. The midrib is continuous to the point, and the nervures run off from it nearly at right angles. In some of these ferns the fructification is known to have been marginal, as in *Pteris*.

Fig. 167.—*Tree Ferns.*



A, *Megaphyton magnificum*, restored. B[1], Row of Leaf-scars, reduced.
B, Leaf-scar of the same, $\frac{3}{8}$ nat. size. C, Palæopteris Harttii, scars half nat. size.
D, Palæopteris Acadica, scars half nat. size.

9. *Pecopteris*, Brongn.—This genus is intermediate between the last and *Neuropteris*. The leaflets are attached by the whole base, but not usually attached to each other; the midrib, though slender, attains to the summit; the nervures are given off less obliquely than in Neuropteris. This genus includes a large number of our most common fossil ferns.

10. *Beinertia*, Goeppert.—A genus established by Goeppert for a curious Pecopteris-like fern, with flexuous branching oblique nervures becoming parallel to the edge of the frond. I have placed in it, with some uncertainty, one of our species.

11. *Hymenophyllites*, Goeppert.—These are ferns similar to *Sphenopteris*, but divided at the margin into *one-nerved* lobes, in the manner of the modern genus *Hymenophyllum*.

12. *Palæopteris*, Geinitz.—This is a genus formed to include certain trunks of tree ferns with oval transverse scars of leaves.

13. *Caulopteris*, Lindley and Hutton,—is another genus of fossil trunks of tree ferns, but with elongate scars of leaves.

14. *Psaronius*, Cotta.—Includes other trunks of tree ferns with alternate scars or thick scales, and ordinarily with many aërial roots grouped round them, as in some modern tree ferns.

15. *Megaphyton*, Artis.—Includes trunks of tree ferns which bore their fronds, which were of great size, in two rows, one on each side of the stem. These were very peculiar trees, less like modern ferns than any of the others (Fig. 167). My reasons for regarding them as ferns are stated in the following extract from a recent paper:—

"Their thick stems, marked with linear scars and having two rows of large depressed areoles on the sides, suggest no affinities to any known plants. They are usually ranked with *Lepidodendron* and *Ulodendron*, but sometimes, and probably with greater reason, are regarded as allied to tree ferns. At the Joggins a very fine species (*M. magnificum*) has been found, and at Sydney a smaller species (*M. humile*); but both are rare and not well preserved. If the large scars bore cones and the smaller bore leaves, then, as Brongniart remarks, the plant would much resemble *Lepidophloios*, in which the cone-scars are thus sometimes distichous. But the scars are not round and marked with radiating scales as in *Lepidophloios;* they are reniform or oval, and resemble those of tree ferns, for which reason they may be regarded as more probably leaf-scars; and in that case the smaller linear scars would indicate ramenta, or small aërial roots. Further, the plant described by Corda as *Zippea disticha* is evidently a *Megaphyton*, and the structure of that species is plainly that of a tree fern of somewhat peculiar type. On these grounds I incline to the opinion of Geinitz,

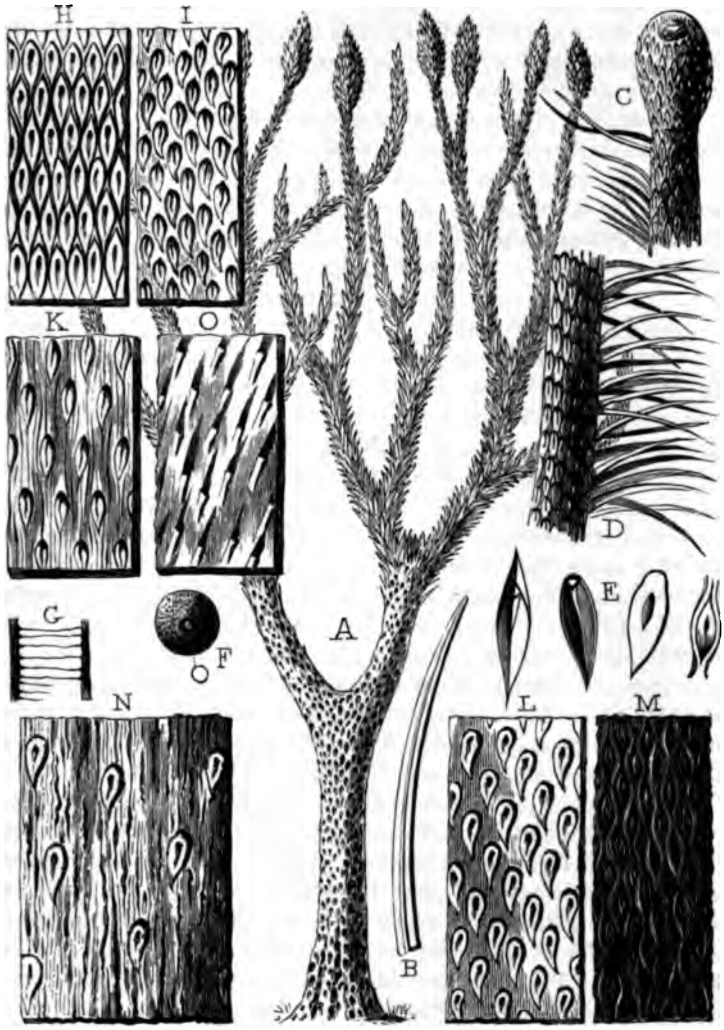
that these curious trees were allied to ferns, and bore two rows of large fronds, the trunks being covered with coarse hairs or small aërial roots. At one time I was disposed to suspect that they may have crept along the ground; but a specimen from Sydney shows the leaf-stalks proceeding from the stem at an angle so acute that the stem must, I think, have been erect. From the appearance of the scars it is probable that only a pair of fronds were borne at one time at the top of the stem; and if these were broad and spreading, it would be a very graceful plant. To what extent plants of this type contributed to the accumulation of coal I have no means of ascertaining, their tissues in the state of coal not being distinguishable from those of ferns and Lycopodiaceæ."

3. *Lycopodiaceæ.*

1. *Lepidodendron*, Sternberg.—This genus is one of the most common in the Coal formation, and especially in its lower part. Any one who has seen the common Ground-pine or Club-moss of our woods, and who can imagine such a plant enlarged to the dimensions of a great forest tree, presenting a bark marked with rhombic or oval scars of fallen leaves, having its branches bifurcating regularly, and covered with slender pointed leaves, and the extremities of the branches laden with cones or spikes of fructification, has before him this characteristic tree of the coal forests,—a tree remarkable as presenting a gigantic form of a tribe of plants existing in the present world only in low and humble species. Had we seen it growing, we might have at first mistaken it for a pine, but the spores contained in its cones, instead of seeds, and its dichotomous ramification, would undeceive us; and if we cut into its trunk, we should find structures quite unlike those of pines. As in *Sigillaria*, we should perceive a large central pith, and surrounding this a ring of woody matter; but instead of finding this partly of disc-bearing wood cells, as in *Sigillaria*, and divided into regular wedges by medullary rays, we should find it a continuous cylinder of coarser and finer scalariform vessels. Outside of this, as in *Sigillaria*, we should have a thick bark, including many tough elongated bast fibres, and protected externally by a hard and durable outer rind. The *Lepidodendra* were large and graceful trees, and contributed not a little to the accumulation of coal. Several attempts have been made to divide this genus. My own views on the subject are given below.

Of this genus nineteen species have been recorded as occurring in the Carboniferous rocks of Nova Scotia. Of these, six occur at the Joggins, where specimens of this genus are very much less abundant than those of *Sigillaria*. In the newer Coal formation, *Lepidodendra*

Fig. 168.—*Lepidodendron corrugatum.*



A. Restoration.
B, Leaf, nat. size.
C, Cone and branch.
D, Branch and leaves.
E, Various forms of leaf areoles.
F, Sproangium.
G, Scalariform vessel, magnified.
H, I, K, L, M, Bark with leaf-scars.
N, Do. of old stem.
O, Decorticated stem (Knorria).

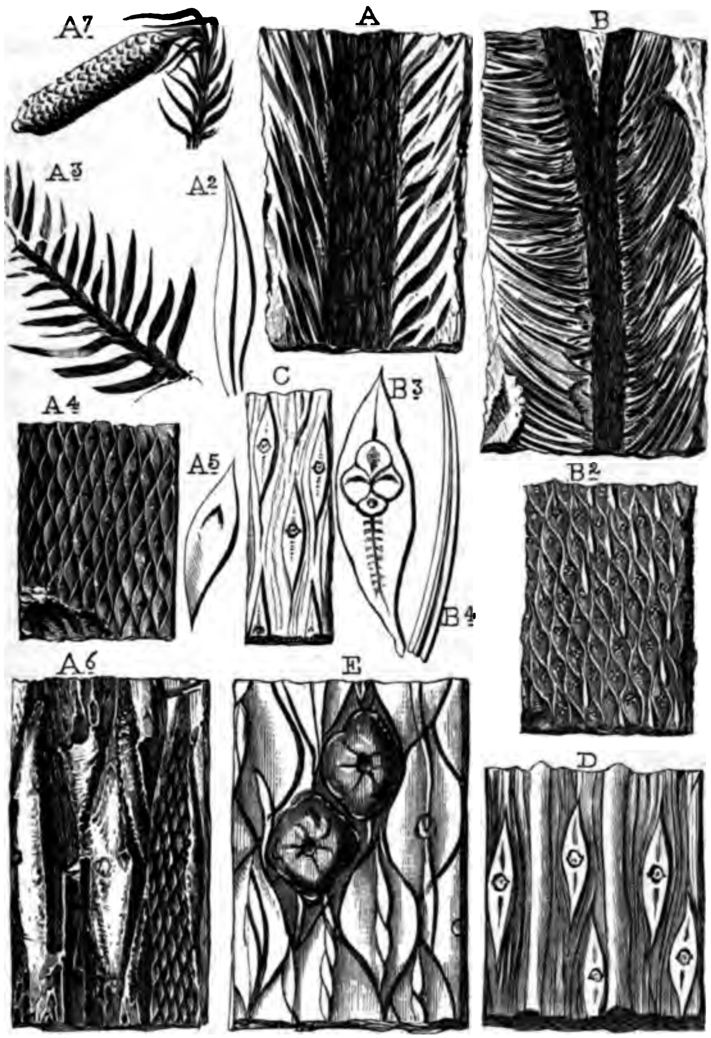
are particularly rare, and *L. undulatum* is the most common species. In the Middle Coal formation, *L. rimosum*, *L. dichotomum*, *L. elegans*, and *L. Pictoense* are probably the most common species; and *L. corrugatum* is the characteristic *Lepidodendron* of the Lower Carboniferous, in which plants of this species seem to be more abundant than any other vegetable remains whatever.

To the natural history of this well-known genus I have little to add, except in relation to the changes which take place in its trunk in the process of growth, and the study of which is important in order to prevent the undue multiplication of species. These are of three kinds. In some species the areoles, at first close together, become, in the process of the expansion of the stem, separated by intervening spaces of bark in a perfectly regular manner; so that in old stems, while widely separated, they still retain their arrangement, while in young stems they are quite close to one another. This is the case in *L. corrugatum*. In other species the leaf-scars or areoles increase in size in the old stems, still retaining their forms and their contiguity to each other. This is the case in *L. undulatum*, and generally in those *Lepidodendra* which have very large areoles. In these species the continued vitality of the bark is shown by the occasional production of lateral strobiles on large branches, in the manner of the modern Red Pine of America. In other species the areoles neither increase in size nor become regularly separated by growth of the intervening bark; but in old stems the bark splits into deep furrows, between which may be seen portions of bark still retaining the areoles in their original dimensions and arrangement. This is the case with *L. Pictoense*. This cracking of the bark no doubt occurs in very old trunks of the first two types, but not at all to the same extent. I figure three examples of these peculiarities in mode of growth:—

Lepidodendron corrugatum, Dawson.—I give below a description of this species, and may refer to the figures in Fig. 168 for further illustration. I do not know any other species in Nova Scotia which has precisely the same habit of growth; but *L. plicatum* and *L. rimosum* show a tendency to it. The present species is exclusively Lower Carboniferous, and occurs on that horizon in New Brunswick, in Pennsylvania, and, I believe, also in Ohio; though the beds holding it in the latter State have been by some regarded as Devonian.

L. undulatum, Sternberg.—I think it not improbable that several closely allied species are included under this name. On the other hand, all the large areoled *Lepidodendra* figured in the books must have branches with small scars, which in the present state of know-

Fig. 169.—*Lepidodendra of Middle Coal Formation.*



A, Branch and leaves of L. Pictoense, ⅔ nat. size. A^2, Leaf. A^3, Twig and leaves, ⅔. A^4, Portion of bark, ⅔. A^5, Leaf-scar. A^6, Bark of old stem furrowed by growth, ⅔. A^7, Cone, ⅔.
B, L. personatum, leafy branch, ⅔. B^2, Portion of bark, ⅔. B^3, Areole enlarged. B^4, Leaf.
C, L. plicatum, bark of old stem.
D, L. rimosum, old stem with furrows, ⅔.
E, L. Undulatum, showing furrows and scars of cones, ⅔.

ledge, it is impossible to identify with this species. I suppose that *L. elegans* resembles the present species in its mode of growth, at least if the large-scarred specimens attributed to it are really of the same species. *L. dichotomum* (= *L. Sternbergii*) also resembles it to some extent (Fig. 169, E).

L. Pictoense, Dawson.—This species I described as follows, from young stems, in my "Synopsis of the Coal-plants of Nova Scotia:"—"Areoles contiguous, prominent, separated in young stems by a narrow line, long-oval, acuminate; breadth to length as 1 to 3, or less; lower half obliquely wrinkled, especially at one side. Middle line indistinct. Leaf-scar at upper end of areole, small, triangular, with traces of three vascular points, nearly confluent. Length of areole about 0·5 inch."

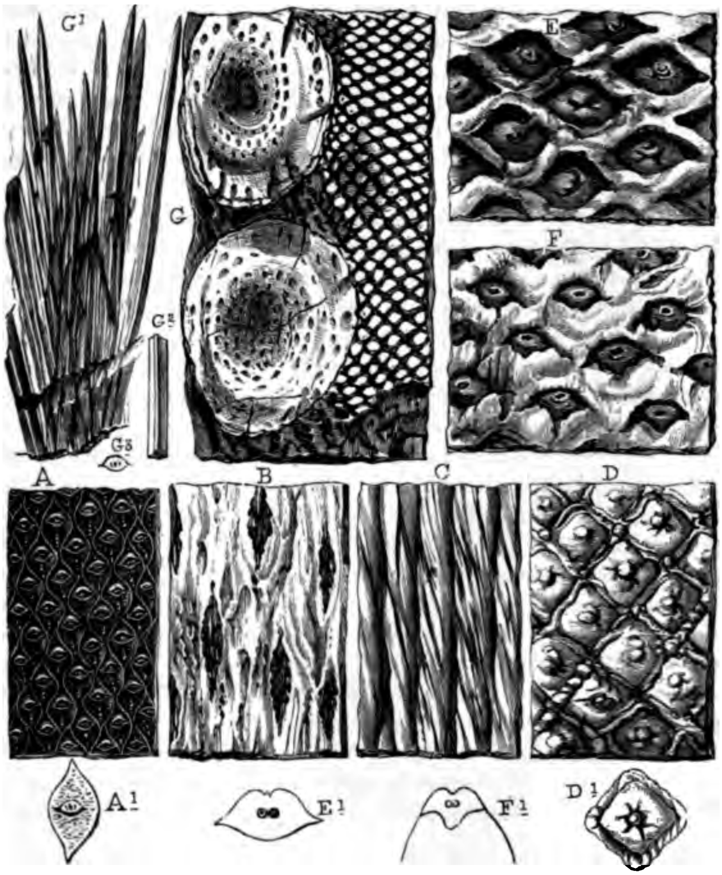
Additional specimens from Sydney show that in old trunks of this species the areoles do not enlarge, but the bark becomes split into strips. I have reason to think that a new species from Nova Scotia, which I shall describe in the sequel, *L. personatum*, agrees with it in this respect (Fig. 169, A, B).

The *Lepidodendra* resemble each other too closely to admit of good sub-generic distinction. The grounds on which the distinction of *Sagenaria* and *Aspidiaria* is founded are quite worthless, the apparent position of the vascular scars in the areoles depending on accidents of preservation much more than on original differences. The genus *Knorria* includes many peculiar conditions of decorticated *Lepidodendra*.

In regard to the accumulation of coal, *Lepidodendra*, when present, appear under the same conditions with *Sigillariæ*, the outer bark being converted into shining coal, and the scalariform axis appearing as mineral charcoal of a more loose and powdery quality than that derived from *Sigillaria*. On the planes of lamination of the coal the furrowed bark of old trunks can scarcely be distinguished from that of old *Sigillariæ* (Fig. 170, B, C).

2. *Lepidophloios*.—Under this generic name, established by Sternberg, I propose to include those Lycopodiaceous trees of the Coal measures which have thick branches, transversely elongated leaf-scars, each with three vascular points and placed on elevated or scale-like protuberances, long one-nerved leaves, and large lateral strobiles in vertical rows or spirally disposed. Their structure resembles that of *Lepidodendron*, consisting of a *Sternbergia* pith, a slender axis of large scalariform vessels, giving off from its surface bundles of smaller vessels to the leaves, a very thick cellular bark, and a thin dense outer bark, having some elongated cells or bast tissue on its inner side.

Fig. 170.—*Lepidodendron and Lepidophloios.*



A, Lepidodendron decurtatum; A¹, areole enlarged.
B, Lepidodendron, old bark.
C, Lepidodendron, old bark, of another species.
D, Lepidophloios tetragonus, $\frac{2}{3}$. D¹, Areole.
E, Lepidophloios platystigma, $\frac{2}{3}$. E¹, Areole.
F, Lepidophloios platystigma, $\frac{2}{3}$, differently preserved. F¹, Areole.
G, Lepidophloios parvus, $\frac{2}{3}$. G¹, Leaves, $\frac{2}{3}$. G², Part of leaf. G³, Areole, natural size.

Regarding *L. laricinum* of Sternberg as the type of the genus, and taking in connexion with this the species described by Goldenberg, and my own observations on numerous specimens found in Nova Scotia, I have no doubt that *Lomatophloios crassicaulis* of Corda, and other species of that genus described by Goldenberg, *Ulodendron* and *Bothrodendron* of Lindley, *Lepidodendron ornatissimum* of Brongniart, and *Halonia punctata* of Geinitz, all belong to this genus, and differ from each other only in conditions of growth and preservation. Several of the species of *Lepidostrobus* and *Lepidophyllum* also belong to *Lepidophloios*.

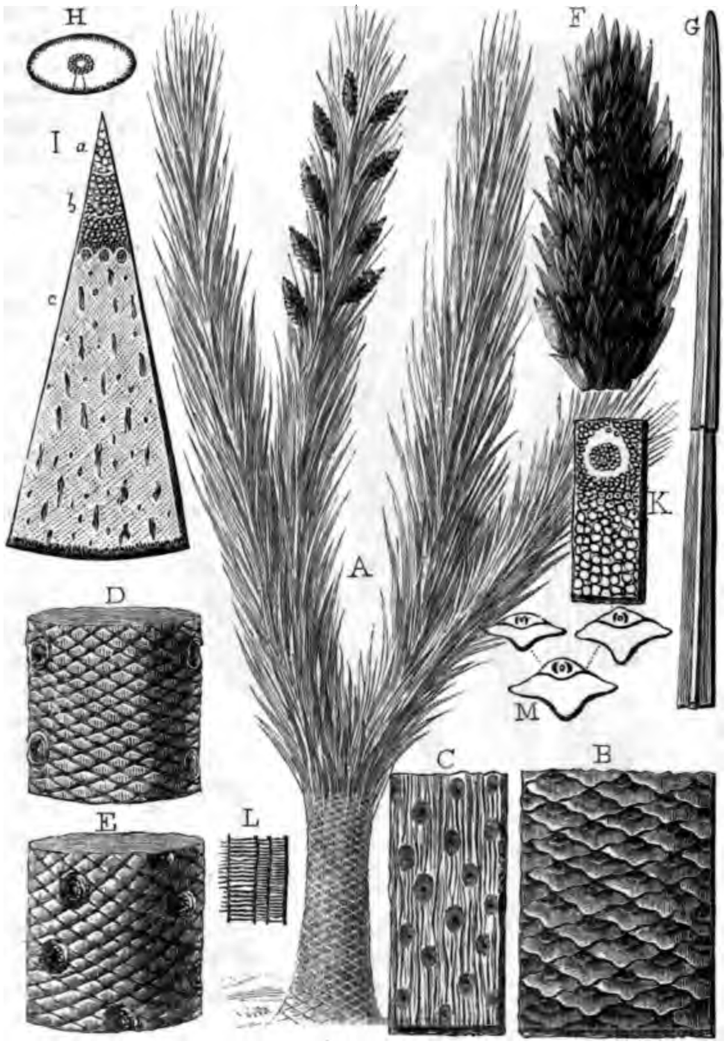
The species of *Lepidophloios* are readily distinguished from *Lepidodendron* by the form of the areoles, and by the round scars on the stem, which usually mark the insertion of the strobiles, though in barren stems they may also have produced branches; still the fact of my finding the strobiles *in situ* in one instance, the accurate resemblance which the scars bear to those left by the cones of the Red Pine when borne on thick branches, and the actual impressions of the radiating scales in some specimens, leave no doubt in my mind that they are usually the marks of cones; and the great size of the cones of *Lepidophloios* accords with this conclusion.

The species of *Lepidophloios* are numerous, and individuals are quite abundant in the Coal formation, especially toward its upper part. Their flattened bark is frequent in the coal-beds and their roofs, affording a thin layer of pure coal, which sometimes shows the peculiar laminated or scaly character of the bark when other characters are almost entirely obliterated. The leaves also are nearly as abundant as those of *Sigillaria* in the coal-shales. They can readily be distinguished by their strong angular midrib.

I figure, in illustration of the genus, all the parts known to me of *L. Acadianus*, and characteristic specimens of other species. One of these, *L. parvus*, is characteristic of the Upper Coal formation. (*Vide* Figs. 170, 171.)

3. *Cordaites* or *Pychnophyllum*.—This plant is represented in the Coal formation chiefly by its broad striated leaves, which are extremely abundant in the coal and its associated shales. Some thin coals are indeed almost entirely composed of them. The most common species is *C. borassifolia*, a plant which Corda has shown to have a simple stem with a slender axis of scalariform vessels resembling that of *Lepidophloios;* for this reason, notwithstanding the broad and parallel-veined leaves, I regard this genus as belonging to *Lycopodiaceæ*, or some allied family. It must have been extremely abundant in the Carboniferous swamps; and, from the frequency of

Fig. 171.—*Lepidophloios Acadianus.*



A, Restoration.
B, Portion of bark, $\frac{2}{3}$ natural size.
C, Ligneous surface of the same.
D, Lower side of a branch, with scars of cones.
E, Upper side of the same.
F, Cone, $\frac{2}{3}$.
G, Leaf, natural size.
H, Cross section of stem, reduced.
I, Portion of the same, nat. size, showing (*a*) pith, (*b*) cylinder of scalariform vessels, (*c*) inner bark.
K, Portion of woody cylinder, showing outer and inner series of vessels magnified.
L, Scalariform vessels, highly magnified.
M, Various forms of leaf scars, natural size.

Fig. 172.—*Cordaites and Diplotegium.*

A, Cordaites borassifolia restored.
A1. Portion of stem.
A2, Portion of leaf, enlarged.
A3, Base of leaf.
A4, Point of leaf.
A5, Transverse section of stem, showing axis.
B, Fragment of stem of Diplotegium retusum.
B1, Scar of do. enlarged.

its being covered with *Spirorbis*, I think it must either have been of more aquatic habit than most of the other plants of the Coal formation, or that its leaves must have been very durable. While the leaves are abundant, the stems are very rare. I infer that they were usually low and succulent. Much of the tissue found in the coal, which I have called "epidermal," probably belongs to leaves of *Cordaites* (Fig. 172).

In the Upper Coal formation there is a second species, distinguished by its simple and uniform venation. This I have named *C. simplex*.

4. *Sporangites*.—To avoid the confusion which envelopes the classification of Carpolites, I have used the above name for rounded spore-cases of *Lepidodendron* and allied plants, which are very frequent in the coal. A smooth round species like a mustard-seed is excessively abundant in the Lower Carboniferous at Horton, and probably belongs to *Lepidodendron corrugatum*, with which it is associated. A species covered with papillæ, *S. papillata*, constitutes nearly the whole of some layers in coal 12, group xix. of the Joggins section. I have no indication as to the plant to which it may belong, except that it is associated with *Cordaites* (Fig. 173, L).

Fruits, Flowers, etc.

1. *Antholithes*, Brongn.—Spikes of fruits protected by bracts, and which I believe to have been produced by Sigillarioid trees (Fig. 173, A, B, C).

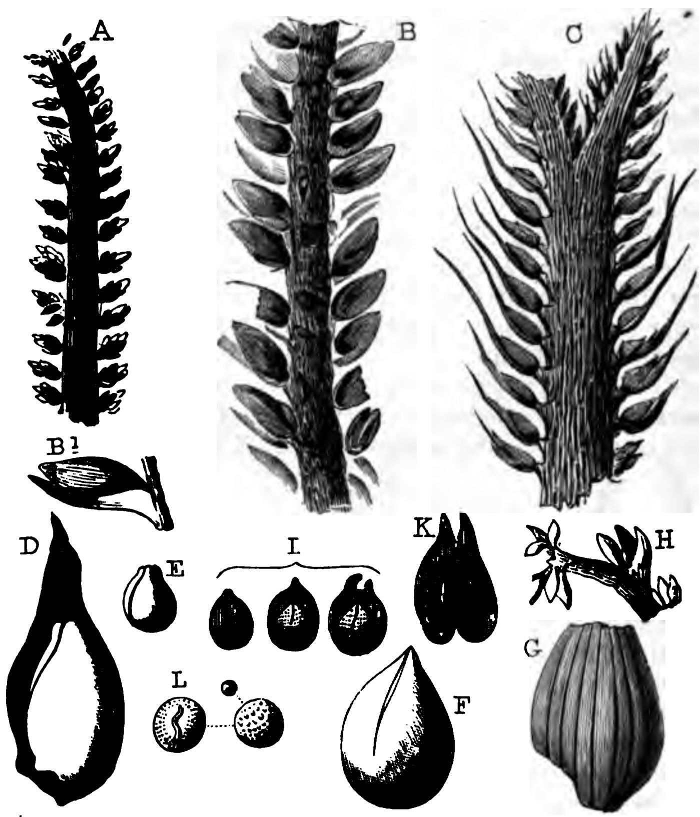
2. *Trigonocarpum*, Brongn.—Nut-like fruits, often three or six angled; with a structure akin to those of Pines and Cycads. I believe most of them to have belonged to *Sigillaria*, some possibly to conifers (Fig. 173, D, E, F, and Fig. 174).

3. *Rhabdocarpus*, Goeppert and Brongn.—Oval fruits with striated sides, often of large size, but of uncertain affinities (Fig. 173, G).

4. *Cardiocarpum*, Brongn.—Fringed or margined fruits resembling Samaras of elms. Their precise origin is unknown. They may have belonged to upland trees, of which we have no other evidence in the coal swamps. It is to be observed, however, that in books of fossil botany, many organisms, which are probably spore-cases of *Lepidodendra* or allied plants, are confounded with true *Cardiocarpa* (Fig. 173, I, K).

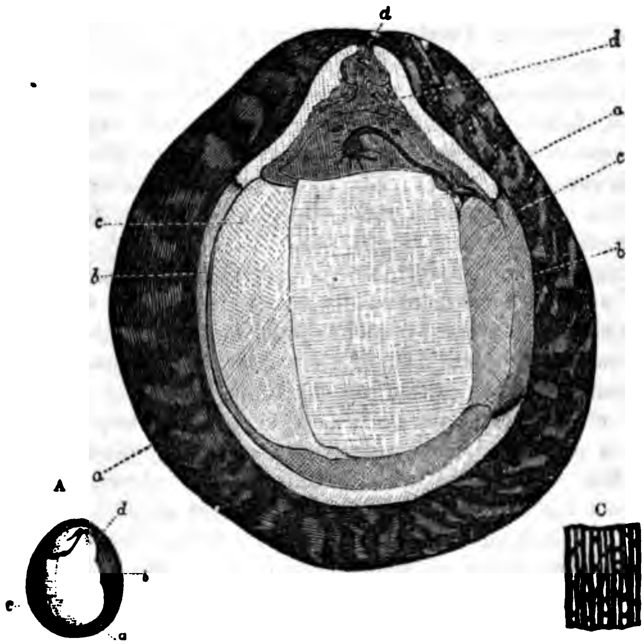
With the exception of a few other genera based on parts of plants, like *Cyperites* and *Stigmaria*, and two specimens referred to *Nœggerathia* (Fig. 73), and *Diplotegium* (Fig. 172, B), genera of uncertain affinities, the above will include all the plants that have as yet been found in our Coal formation; and they are the characteristic genera of the Carboniferous period throughout the world.

Fig. 173.—*Flowers and Fruits*—Coal Formation.



A, Antholithes squamosus, [illegible].
B, A. rhabdocarpi, [illegible]. B[1], Carpel restored.
C, A. spinosus, natural size.
D, Trigonocarpum intermedium.
E, T. Nœggerathii.
F, T. avellanum.
G, Rhabdocarpus insignis, reduced.
H, Antholithes pygmæus.
I, Cardiocarpum fluitans.
K, Cardiocarpum bisectum.
L, Sporangites papillata, nat. size and mag.

Fig. 174.—*Trigonocarpum Hookeri*, Dawson; from the Coal measures of Cape Breton.



A, Broken specimen magnified twice natural size.
B, Section magnified: *a*, the testa; *b*, the tegmen; *c*, the nucleus; and *d*, the embryo.
C, Portion of the surface of the inner coat more highly magnified.

Tissues of Plants preserved in the Coal.

This subject has occupied much of my leisure time for some years, and I have published the results of an extensive series of experiments and observations on the Coals of Pictou and Sydney, in a paper on the "Vegetable Structures in Coal," in the Journal of the Geological Society of London, February 1860; and a still more extended series on the numerous coals of the South Joggins, in my memoir on the "Conditions of Deposition of Coal," December 1865. I give here a summary of results of these inquiries.

The direct investigation of the tissues preserved in coal has been pursued to some extent by Witham, Hutton, Goeppert, Brongniart, Bailey, Hooker, Quekett, Harkness, and others. Two difficulties, however, have impeded this investigation, and have in some degree prevented the attainment of reliable results. One of these is the intractable character of the material as a microscopic object; the

other, the want of sufficient information in regard to the structures of the plants known by impressions of their external forms in the beds of the Coal formation. Perplexed by the uncertain and contradictory statements arising from these difficulties, and impressed with the conviction that the coal itself might be made more fully to reveal its own origin, I have for a long time been engaged in experiments and observations with this object, and believe that I can offer definite and certain results in so far as relates to the particular coals examined, and, I have no doubt, with some slight modifications, to all the ordinary coals of the true Coal measures.

In ordinary bituminous coal, we recognise by the unassisted eye laminæ of a compact and more or less lustrous appearance, separated by uneven films and layers of fibrous anthracite or of mineral charcoal, and these two kinds of coal demand a separate consideration.

The substance known by the very appropriate name of "mineral charcoal," consists of fragments of prosenchymatous and vasiform tissues in a carbonized state, somewhat flattened by pressure, and more or less impregnated with bituminous and mineral matters derived from the surrounding mass. We cannot suppose that this substance has escaped complete bituminization on account of its original constitution; for we have abundant evidence that this change has passed upon similar material in various geological periods. A substance so intimately intermixed with the ordinary coal cannot be accounted for by the supposition of forest conflagrations or the action of subterranean heat. The only satisfactory explanation of its occurrence is that afforded by the chemical changes experienced by woody matter decaying in the presence of air, in the manner so well illustrated by Liebig. In such circumstances, wood parts with its hydrogen and oxygen and a portion of its carbon, in the forms of water and carbonic acid; and, as the ultimate result, a skeleton of nearly pure charcoal, retaining the form and structure of the wood, remains. In the putrefaction of wood under water, or imbedded in aqueous deposits, a very different change occurs, in which the principal loss consists of carbon and oxygen; and the resulting coaly product contains proportionally more hydrogen than the original wood. This is the condition of the compact bituminous coal. This last may, by the action of heat, or by long exposure to air and water, lose its hydrogen in the form of hydro-carbons, and be converted into anthracite. In all the ordinary coals we have the products, more or less, of all these processes. The mineral charcoal results from subaërial decay, the compact coal from subaqueous putrefaction, more or less modified by heat and exposure to air. As Dr Newberry has very well shown, in

coals like cannel-coals, which have been formed wholly under subaqueous conditions, the mineral charcoal is deficient.*

A consideration of the decay of vegetable matter in modern swamps and forests shows that all kinds of tissues are not, under ordinary circumstances, susceptible of the sort of carbonization which we find in the mineral charcoal. Succulent and lax parenchymatous tissues decay too rapidly and completely. The bark of trees very long resists decay, and, where any deposition is proceeding, is likely to be imbedded unchanged. It is the woody structure, and especially the harder and more durable wood, that, becoming carbonized and splitting along the medullary rays and lines of growth, affords such fragments as those which we find scattered over the surfaces of the coal.† These facts would lead us to infer that mineral charcoal represents the woody debris of trees subjected to subaërial decay, and that the bark of these trees should appear as compact coal along with such woody or herbaceous matters as might be imbedded or submerged before decay had time to take place.

My method of preparing the mineral charcoal for examination was an improvement on the "nitric-acid" process of previous observers, and the results gave very perfect examples of the disc-bearing tissue restricted in the modern world to conifers and cycads, but which existed also in the *Sigillariæ* of the Coal period. With this were scalariform vessels, like those of ferns and club mosses, and several other kinds of woody tissue. On careful comparison, it was found that all these tissues might be referred to the following genera of plants common in the Coal measures: *Sigillaria*, including *Stigmaria*, *Calamites*, *Dadoxylon*, and other conifers, *Lepidodendron*, *Ulodendron*, ferns, and possibly some other less known plants. Another form of tissue observed was a large spiral vessel, possibly belonging to some endogenous plant. The perfect state of preservation of these tissues may be inferred from the following figures, selected from those prepared for my paper (Fig. 175).

I shall first notice in detail the structures preserved in the layers of shining compact coal, and afterwards those found in the mineral charcoal.

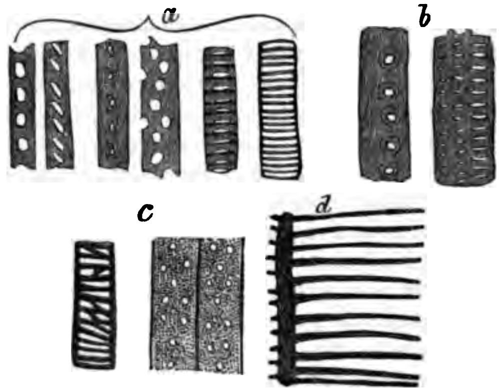
I. The compact coal, constituting a far larger proportion of the mass than the "mineral charcoal," consists either of lustrous conchoidal *cherry* or *pitch coal*,—of less lustrous *slate coal*, with flat

* American Journal of Science. See also Goeppert, "Abhandlung uber Steinkohlen;" also a paper by the author, "On Fossils from Nova Scotia," Quart. Journ. Geol. Soc. 1846.

† See paper of 1846, previously cited.

fracture,—or of coarse coal, containing much earthy matter. All of these are arranged in thin interrupted laminæ. They consist of

Fig. 175.—*Tissues from Coal.*



(*a*) Tissues of axis of Sigillaria. (*b*) Tissues of Calamites?
(*c*) Tissues of Ferns. (*d*) Scalariform vessel of Lepidodendron.

vegetable matter which has not been altered by subaërial decay, but which has undergone the bituminous putrefaction, and has thereby been resolved into a nearly homogeneous mass, which still, however, retains traces of structure and of the forms of the individual flattened plants composing it. As these last are sometimes more distinct than the minute structures, and are necessary for their comprehension, I shall, under the following heads, notice both as I have observed them in the coals in question :—

1. The laminæ of pitch or cherry coal, when carefully traced over the surfaces of accumulation, are found to present the outlines of flattened trunks. This is also true, to a certain extent, of the finer varieties of slate coal; but the coarse coal appears to consist of extensive laminæ of disintegrated vegetable matter mixed with mud.

2. When the coal (especially the more shaly varieties) is held obliquely under a strong light, in the manner recommended by Goeppert, the surfaces of the laminæ present the forms of many well-known coal-plants, as *Sigillaria*, *Stigmaria*, *Cordaites*, *Lepidodendron*, *Lepidophloios*, and rough bark, perhaps of conifers.

3. When the coal is traced upward into the roof-shales, we often find the laminæ of compact coal represented by flattened coaly trunks and leaves, now rendered distinct by being separated by clay.

4. In these flattened trunks it is the outer cortical layer that alone constitutes the coal. This is very manifest when the upper and under

bark are separated by a film of clay or of mineral charcoal, occupying the place of the wood. In this condition the bark of a large Sigillaria gives only one or two lines in thickness of coal; *Stigmaria*, *Lepidodendron*, and *Ulodendron* give still less. In the shales these flattened trunks are often so crushed together that it is difficult to separate them. In the coal they are, so to speak, fused into a homogeneous mass.

5. The phenomena of erect forests explain to some extent the manner in which layers of compact coal and mineral charcoal may result from the accumulation of trunks of trees *in situ*. In the sections at the South Joggins, the usual state of preservation of erect *Sigillariæ* is that of casts in sandstone, enclosed by a thin layer of bark converted into compact, caking, bituminous coal, while the remains of the woody matter may be found in the bottom of the cast in the state of mineral charcoal. In other cases the bark has fallen in, and all that remains to indicate the place of a tree is a little pile of mineral charcoal, with strips of bark converted into compact coal. Lastly, a series of such remains of stumps, with flattened bark of prostrate trunks, may constitute a rudimentary bed of coal, many of which exist in the Joggins section. In short, a single trunk of *Sigillaria* in an erect forest presents an epitome of a coal-seam. Its roots represent the Stigmaria underclay; its bark the compact coal; its woody axis the mineral charcoal; its fallen leaves, with remains of herbaceous plants growing in its shade, mixed with a little earthy matter, the layers of coarse coal. The condition of the durable outer bark of erect trees concurs with the chemical theory of coal, in showing the especial suitableness of this kind of tissue for the production of the purer compact coals. It is also probable that the comparative impermeability of bark to mineral infiltration is of importance in this respect, enabling this material to remain unaffected by causes which have filled those layers consisting of herbaceous materials and decayed wood, with earthy matter, pyrites, etc.

6. The microscopic structure of the purer varieties of compact coal accords with that of the bark of *Sigillaria*. The compact coals are capable of affording very little true structure. Their cell-walls have been pressed close together; and pseudo-cellular structures have arisen from molecular action and the segregation of bituminous matter. Most of the structures which have been figured by microscopists are of this last character, or at the utmost are cell-structures masked by concretionary action, pressure, and decay. Hutton, however, appears to have ascertained a truly cellular tissue in this kind of coal. Goeppert also has figured parenchymatous and perhaps bast-tissues obtained from its incineration. By acting on it with nitric

acid, I have found that the structures remaining both in the lustrous compact coals and in the bark of *Sigillariæ* are parenchymatous cells and fibrous cells, probably bast-fibres.

7. I by no means desire to maintain that all portions of the coal-seams not in the state of mineral charcoal consist of cortical tissues. Quantities of herbaceous plants, leaves, etc., are also present, especially in the coarser coals; and some small seams appear to consist entirely of such material,—for instance, of the leaves of *Cordaites* or *Poacites*. I would also observe that, though in the roof-shales and other associated beds it is usually only the cortical layer of trees that appears as compact bituminous coal, yet I have found specimens which show that in the coal-seams themselves true woody tissues have sometimes been imbedded unchanged, and converted into structureless coal, forming, like the coniferous trees converted into jet in more modern formations, thin bands of very pure bituminous material. The proportion of woody matter in this state differs in different coals, and is probably greatest in those which show the least mineral charcoal; but the alteration which it has undergone renders it almost impossible to distinguish it from the flattened bark, which in all ordinary cases is much more abundant.

II. In the mineral charcoal, which affords the greater part of the material showing distinct vegetable structures, the following kinds of tissue are those ordinarily observed:—

a. *Bast tissue, or elongated cells from the liber or inner bark of* Sigillariæ *and* Lepidodendron, *but especially of the former.*—This kind of tissue is abundant in a calcified state in the shales associated with the coals, and also as mineral charcoal in the coals themselves, and in the interior of erect *Sigillariæ*. It is the kind of tissue figured by Brongniart as the inner layer of bark in *Sigillaria elegans*, and very well described by Binney (Quart. Journ. Geol. Soc. vol. xviii.) as "elongated tissue or utricles." Under the microscope many specimens of it closely resemble the imperfect bast tissue of the inner bark of *Pinus strobus* and *Thuja occidentalis;* and like this it seems to have been at once tough and durable, remaining in fibrous strips after the woody tissues had decayed. It is extremely abundant at the Joggins in the mineral charcoal of the smaller coal-seams. It is often associated with films of structureless coal, which represent the dense cellular outer bark which, in the trunk of *Sigillaria*, not only surrounded this tissue, but was intermixed with it.

b. *Vascular bundles of Ferns.*—These may be noticed by all close observers of the surfaces of coal, as slender hair-like fibres, sometimes

lying separately, in other cases grouped in bands half an inch or more in diameter, and embedded in a loose sort of mineral charcoal. When treated with nitric acid, each bundle resolves itself into a few scalariform vessels surrounded with a sheath of woody fibres, often minutely porous. This structure is precisely that of macerated fern-stipes; but, as already stated, there may have been some other coal-plants whose leaves presented similar bundles. As stated in my former paper "On the Vegetable Structures in Coal," this kind of tissue is especially abundant in the coarse and laminated portions of the coal, which we know on other evidence to have been made up, not of trunks of trees, but of mixed herbaceous matters (Fig. 175, C).

c. *Scalariform vessels.*—These are very abundant in the mineral charcoal, though the coarser kinds have been crushed and broken in such a manner that they usually appear as mere debris. The scalariform vessels of *Lepidodendron*, *Lepidophloios*, and *Stigmaria* are very coarse, and much resemble each other. Those of ferns are finer, and sometimes have a reticulated structure. Those of *Sigillaria* are much finer, and often have the aspect of wood-cells with transversely elongated pores like those of *Cycas*. Good examples of these are figured in the paper already referred to (see also Fig. 175, A and D).

d. *Discigerous wood-cells.*—These are the true bordered pores characteristic of *Sigillaria*, *Calamodendron*, and *Dadoxylon*. In the two former genera the discs or pores are large and irregularly arranged, either in one row or several rows; but in the latter case they are sometimes regularly alternate and contiguous. In the genus *Dadoxylon* they are of smaller size, and always regularly contiguous in two or more rows, so as to present an hexagonal areolation. Discigerous structures of *Sigillaria* and *Calamodendron* are very abundant in the coal, and numerous examples were figured in my paper above cited. I have indicated by the name *Reticulated Tissue* certain cells or vessels which may either be reticulated scalariform vessels, or an imperfect form of discigerous tissue. I believe them to belong to *Stigmaria* or *Calamodendron* (Figs. 162 and 175, A.)

e. *Epidermal tissue.*—This is a dense cellular tissue representing the outer integuments of various leaves, herbaceous stems, and fruits. I have ascertained that the structures in question occur in the leaves and stipes of *Cordaites* and ferns, and in the outer coat of *Carpolites* and *Sporangites*. With this I may include the obscure and thick-walled cellular tissue of the outer bark of *Sigillaria* and *Lepidodendron* and other trees, which, though usually consolidated into compact coal, sometimes exhibits its structure.

I would here emphatically state that all my observations at the Joggins confirm the conclusion, which I arrived at many years ago from the study of the coals of Pictou and Sydney, that the layers of clear shining coal (pitch or cherry coal) are composed of flattened trunks of trees, and that of these usually the bark alone remains; further, that the lamination of the coal is due to the superposition of layers of such flattened trunks alternating with the accumulations of vegetable matter of successive years, and occasionally with fine vegetable muck or mud spread over the surface by rains or by inundations. In connexion with this, it is to be observed that the density and *impermeability* of cortical tissues not only enable them to endure after wood has perished or been resolved into bits of charcoal, but render them less liable than the wood to mineral *infiltration*.

Rate of Growth of Carboniferous Plants.—Very vague statements are often made as to the supposed rapid rate of growth of plants in the Carboniferous period. Perhaps the most trustworthy facts in relation to this subject are those which may be obtained from the coniferous trees. In some of these (for instance, *Dadoxylon materiarium*, *D. annulatum*, and *D. antiquius*) the rings of growth, which were no doubt annual, are distinctly marked. On measuring these in a number of specimens, and comparing them with modern species, I find that they are about equal in dimensions to those of the Balsam Fir or the Yellow Pine of America. Assuming, therefore, similarity in habit of growth and extent of foliage to these species, we may infer that, in regard to coniferous trees, the ordinary conditions of growth were not dissimilar from those of Eastern America in its temperate regions at present. When, however, we compare the ferns and *Lycopodiaceæ* of the Coal formation with those now growing in Eastern America, we see, in the much greater dimensions and luxuriance of the former, evidence of a much more moist and equable climate than that which now subsists; so that we may suppose the growth of such plants to have been more rapid than it is at present. These plants would thus lead us to infer a warm and insular climate, perhaps influenced by that supposed excess of carbonic acid in the atmosphere which, as Tyndall and Hunt inform us, would promote warmth and moisture by impeding terrestrial radiation. With this would also agree the fact that the conifers have woody tissues resembling those of the pine trees of the milder climates of the southern hemisphere at present.

If we apply these considerations to *Sigillaria*, we may infer that the conditions of moisture and uniformity of temperature favourable to ferns and *Lycopodiaceæ* were also favourable to these curious

plants. They must have been perennial; and the resemblance of their trunks to those of Cycads, together with their hard and narrow leaves, would lead us to infer that their growth must have been very slow. A similar inference may be drawn from the evidences of very slow and regular expansion presented by the lower parts of their stems. On the other hand, the distance, of a foot or more, which often intervenes between the transverse rows of scars, marking possibly annual fructification, would indicate a more rapid rate of growth. Further, it may be inferred, from the structure of their roots and of their thick inner bark, that these, as in Cycads, were receptacles for great quantities of starch, and that the lives of these plants presented alternations of starch-accumulation and of expenditure of this in the production of leaves, wood, and abundant inflorescence. They would thus, perhaps for several years, grow very slowly, and then put forth a great mass of fructification, after which perhaps many of the individuals would die, or again remain for a long time in an inactive state. This view would, I think, very well harmonize with the structure of these plants, and also with the mode of their entombment in the coal.

From the manner of the association of Calamites with erect *Sigillariæ*, I infer that the former were, of all the plants of the Coal formation, those of most rapid dissemination and growth. They appear to have first taken possession of emerging banks of sand and mud, to have promoted the accumulation of sediment on inundated areas, and to have protected the exposed margins of the forests of *Sigillariæ*.

In applying any conclusions as to the rate of growth of Carboniferous plants to the accumulation of coal, we must take into account the probable rate of decay of vegetable matter. When we consider the probable wetness of the soils on which the plants which produced the coal grew, the density of the forests, and the possible excess of carbonic acid in the atmosphere of these swamps, we must be prepared to admit that, notwithstanding the warmth and humidity, the conditions must have been favourable to the preservation of vegetable matter. Still the hollow cylinders of bark, the little fragments of decayed wood in the form of mineral charcoal, and the detached vascular bundles of ferns, testify to an enormous amount of decay, and show that, however great the accumulation of coal, it represents only a fraction of the vegetable matter which was actually produced. It has been estimated that it would require eight feet of compact vegetable matter to produce one foot of coal; but if we reckon the whole vegetable matter actually produced in the process, I should suppose that five times that amount would be far below the truth,

even in the most favourable cases; while there is evidence that in the Carboniferous period many forests may have flourished for centuries without producing an inch of coaly matter.

Summary of Conclusions.—In illustration of the bearing of these facts on the questions relating to the materials of the coal, I give the following table, representing in a condensed form the results of my observations on the coals of the South Joggins:—

Table showing the Relative Frequency of Occurrence of Genera of Plants and Animals in the Coals of the South Joggins.

Name of Fossils.		Division 3. 23 coals.	Division 4. 49 coals.	Division 6. 9 coals.	Total. 81 coals.
Plants.					
Sigillaria	occurs in	13	34	2	49
Cordaites........................	"	15	26	...	41
Filices (mostly *Alethopteris lonchitica*)	"	4	17	2	23
Lepidodendron and Lepidophloios.....	"	1	15	...	16
Calamites	"	4	12	...	16
Carpolites, etc..................	"	2	9	...	11
Asterophyllites	"	1	2	...	3
Calamodendron	"	...	1	...	1
Structures.					
Vascular bundles of ferns ...	"	8	22	...	30
Bast tissue (*Sigillaria*)	"	2	16	2	20
Epidermal tissue (*Cordaites*, etc.)...........................	"	6	6	...	12
Scalariform (*Sigil.*, *Stig.*, *Lepidod.*, etc.)........	"	1	9	1	11
Discigerous (*Sigillaria* and *Dadoxylon*, etc.)............	"	1	8	1	10
Reticulated (*Calamites*, Ferns, etc.)	"	...	2	1	3
Animals.					
Fishes (*Palæoniscus*, *Rhizodus*, etc.)	"	1	16	1	18
Naiadites (*Anthracomya*, etc.)	"	...	16	1	17
Spirorbis carbonarius	"	...	16	...	16
Cythere	"	...	13	1	14
Insects (?)	"	...	3	...	3
Reptiles (*Dendrerpeton*, etc.)	"	...	1	...	1
Pupa vetusta and *Xylobius sigillariæ*	"	...	1	...	1

The number of coals reckoned in this coal-field may vary according to the manner in which the several layers are grouped; but as arranged in the sectional list given in a previous chapter it amounts to eighty-one in all. Of these, 23 are found in Division 3 of Logan's section, being the upper member of the Middle Coal formation; 49 are found in Division 4 of Logan's section, being the lower member of the Middle Coal formation; 9 occur in Division 6 of Logan's section, or in the equivalent of the Millstone-grit. In the latter group few of the coals were sufficiently well exposed to enable a satisfactory examination to be made. I have grouped the remains under three heads—External Forms of Plants, Microscopic Structure of Plants, and Animal Remains—and have arranged the forms under each in the order of their relative frequency of occurrence. No mention is made of *Stigmaria*, which occurs in nearly every coal or its underclay.

The following are the conclusions, based on the above table and on examinations of the Coal of Pictou and Sydney:—

"1. With respect to the plants which have contributed the vegetable matter of the coal, these are principally the *Sigillariæ*, with *Cordaites*, Ferns and *Calamites*. With these, however, are intermixed remains of most of the other plants of the period, contributing, though in an inferior degree, to the accumulation of the mass. This conclusion is confirmed by facts derived from the associated beds,—as, for instance, the prevalence of *Stigmaria* in the underclays, and of *Sigillariæ* and *Calamites* in the roof-shales and erect forests.

"2. The woody matter of the axes of *Sigillariæ* and *Calamiteæ* and of coniferous trunks, as well as the scalariform tissues of the axes of the *Lepidodendreæ* and *Ulodendreæ*, and the woody and vascular bundles of ferns, appear principally in the state of mineral charcoal. The outer cortical envelope of these plants, together with such portions of their wood and of herbaceous plants and foliage as were submerged without subaërial decay, occur as compact coal of various degrees of purity; the cortical matter, owing to its greater resistance to aqueous infiltration, affording the purest coal. The relative amounts of all these substances found in the states of mineral charcoal and compact coal depend principally upon the greater or less prevalence of subaërial decay, occasioned by greater or less dryness of the swampy flats on which the coal accumulated.

"3. The structure of the coal accords with the view that its materials were accumulated by growth, without any driftage of materials. The *Sigillariæ* and *Calamiteæ*, tall and branchless, and clothed only with rigid linear leaves, formed dense groves and jungles, in which the stumps and fallen trunks of dead trees became resolved by decay

into shells of bark and loose fragments of rotten wood, which currents would necessarily have swept away, but which the most gentle inundations or even heavy rains could scatter in layers over the surface, where they gradually became imbedded in a mass of roots, fallen leaves, and herbaceous plants.

"4. The rate of accumulation of coal was very slow. The climate of the period, in the northern temperate zone, was of such a character that the true conifers show rings of growth not larger or much less distinct than those of many of their modern congeners.* The *Sigillariæ* and *Calamites* were not, as often supposed, composed wholly, or even principally, of lax and soft tissues, or necessarily short-lived. The former had, it is true, a very thick inner bark; but their dense woody axes, their thick and nearly imperishable outer bark, and their scanty and rigid foliage, would indicate no very rapid growth or decay. In the case of *Sigillariæ*, the variations in the leaf-scars in different parts of the trunk, the intercalation of new ridges at the surface representing that of new woody wedges in the axis, the transverse marks left by the stages of upward growth—all indicate that several years must have been required for the growth of stems of moderate size. The enormous roots of these trees, and the conditions of the coal-swamps, must have exempted them from the danger of being overthrown by violence. They probably fell, in successive generations, from natural decay; and, making every allowance for other materials, we may safely assert that every foot of thickness of pure bituminous coal implies the quiet growth and fall of at least fifty generations of *Sigillariæ*, and therefore an undisturbed condition of forest-growth enduring through many centuries. Further, there is evidence that an immense amount of loose parenchymatous tissue, and even of wood, perished by decay; and we do not know to what extent even the most durable tissues may have disappeared in this way; so that in many coal-seams we may have only a very small part of the vegetable matter produced.

"*Lastly*, the results stated in this paper refer to coal-beds of the Middle Coal measures. A few facts which I have observed lead me to believe that, in the thin seams of the Lower Coal measures, remains of *Cordaites* and *Lepidodendron* are more abundant than in those of the Middle Coal measures. In the upper Coal measures similar modifications may be expected."

* Paper on Fossils from Nova Scotia, Quart. Journ. Geol. Soc. 1847.

Descriptive List of Carboniferous Plants found in Nova Scotia and New Brunswick.

This list is, with a few additional species and localities, the same with that published in my "Synopsis of the Carboniferous Flora of Nova Scotia," Can. Nat., vol. viii. 1863. It is given here to aid those who may desire to make collections of these interesting fossils, and for comparison with the coal flora of other regions.

DADOXYLON, Unger.

1. *Dadoxylon Acadianum*, spec. nov. (Fig. 159, B). Large trees, usually silicified or calcified, with very wide wood-cells, having three or more rows of small hexagonal areoles, each enclosing an oval pore; cells of medullary rays one-third of breadth of wood-cells, and consisting of twenty or more rows of cells superimposed in two series. Rings of growth indistinct. M. C.,* Joggins, Port Hood, Dorchester (J. W. D.).

2. *D. materiarium*, spec. nov. (Fig. 159, C). Wood-cells less wide than those of the last; two to rarely four rows of hexagonal discs. Medullary rays very numerous, with twenty or more rows of cells superimposed in one series. Rings of growth slightly marked. Approaches in the character of its woody fibre to *D. Brandlingii*; but the medullary rays are much longer. Some specimens show a large Sternbergian pith, with transverse partitions.† Vast numbers of trunks of this species occur in some sandstones of the Upper Coal formation. M. and U. C., Joggins, Malagash, Pictou, etc. (J. W. D.); Glace Bay (H. Poole); Miramichi (G. F. Matthew).

3. *D. antiquius*, spec. nov. (Fig. 159, D). Wood-cells narrow, thick-walled, two to three rows of pores. Medullary rays of three or four series of cells with twenty or more superimposed, nearly as wide as the wood-cells. Rings of growth visible. This species would belong to the genus *Palæoxylon* of Brongniart, and is closely allied to *D. Withami*, L. and H., which, like it, occurs in the Lower Coal measures. L. C., Horton (Dr Harding).

4. *D. annulatum*, spec. nov. Wood-cells with two or three rows of hexagonal discs. Medullary rays of twenty or more rows of cells superimposed, in two series. Wood divided into distinct concentric circles, alternating with layers of structureless coal representing cellular tissue or very dense wood. A stem six inches in diameter has fourteen to sixteen of these rings, and a pyritized pith about

* U. C., M. C., and L. C., indicate the Upper, Middle, and Lower Coal formations.
† Canadian Naturalist, 1857 (Fig. 160, *supra*).

one inch in diameter. This is probably generically distinct from the preceding species. M. C., Joggins (Sir W. E. Logan; J. W. D.).

ARAUCARITES, Unger.

Araucarites gracilis, spec. nov. (Fig. 159, A). Branches slender, 0·2 inch in diameter, with scaly, broad leaf-bases. Branchlets pinnate, numerous, very slender, with small, acute, spirally disposed leaves. U. C., Tatamagouche (J. W. D.).

SIGILLARIA, Brongn.

1. *Sigillaria* (*Favularia*) *elegans*, Brongn. (Fig. 161, B). Abundant, especially in the roofs of coal seams. *S. hexagona* includes old trunks of this species. Young branches have scars of an elliptical form like those of *S. Serlii*. M. C., Joggins (J. W. D.); Sydney (R. Brown).

2. *S.* (*Fav.*) *tessellata*, Brongn. M. C., Joggins and Pictou (J. W. D.); Sydney (R. Brown).

3. *S.* (*Rhytidolepis*) *scutellata*, Brongn. (Fig. 161, L, leaf). M. and U. C., Joggins (Lyell; J. W. D.).

4. *S.* (*Rh.*) *Schlotheimiana*, Brongn. M. C., Joggins (Lyell; J. W. D.).

5. *S.* (*Rh.*) *Saullii*, Brongn. M. C., Sydney (R. Brown); Joggins (Lyell; J. W. D.).

6. *S. Brownii*, Dawson (Quart. Journ. Geol. Soc., vol. x.). (Figs. 30 and 161, A). M. C., Joggins (J. W. D.).

7. *S. reniformis*, Brongn. M. C., Joggins (Lyell; J. W. D.); Sydney (R. Brown).

8. S. *Lævigata*, Brongn. M. C., Sydney (R. Brown); Joggins (J. W. D.).

9. *S. planicosta*, spec. nov. (Fig. 161, K). Scars half hexagonal above, rounded below; lateral vascular impressions elongate; central small, punctiform. Ribs 1·1 inch broad, smooth externally, longitudinally striated on the ligneous surface. Slight transverse wrinkles between the scars, which are distant from each other about an inch. Allied to *S. lævigata*, but with very thin bark. M. C., Sydney (R. Brown).

10. *S. catenoides*, spec. nov. (Fig. 161, I). Cortical surface unknown; ligneous surface with puncto-striate ribs 1·1 inch in breadth, and with single oval scars half an inch long, and an inch distant from centre to centre. A very large tree. Perhaps, if its cortical surface were known, it might prove to be a large *Syringodendron*. M. C., Joggins (J. Smith); Sydney (R. Brown).

11. *S. striata*, spec. nov. (Fig. 161, G). Ribs prominent, coarsely

striate, 0·35 inch wide. Scars nearly as wide as the ribs, rounded, hexagonal, one inch distant; lateral vascular marks narrow, central large. On the ligneous surface scars single, round, oblong; bark very thin. M. C., Joggins (J. W. D.).

12. *S.* —— (?) A small erect stem, somewhat like *S. flexuosa.* M. C., Joggins (J. W. D.).

13. *S.* (*Clathraria*) *Menardi*, Brongn. M. C., Sydney (R. Brown), U. C., Pictou (J. W. D.).

14. *S.* (*Asolanus*) *Sydnensis*, spec. nov. Ribs obsolete; cortical and ligneous surfaces striate; vascular scars two, elongate longitudinally, and alike on cortical and ligneous surfaces; scars 1·1 inch distant, in rows 0·6 inch distant. Stigmarian roots, same with variety *h* of *Stigmaria*, as described below. M. C., Sydney (R. Brown).

15. *S. organum*, L. and H. M. C., Sydney (R. Brown).

16. *S. elongata*, Brongn. M. C., Sydney (R. Brown).

17. *S. flexuosa*, L. and H. M. C., Sydney (R. Brown's list in "Acadian Geology").

18. *S. pachyderma*, L. and H. M. C., Sydney (R. Brown's list).

19. *S.* (*Fav.*) *Bretonensis*, spec. nov. (Fig. 161, F). Like *S. tessellata*, but areoles more hexagonal, bark thin and smooth on both sides, and furrow above the scars arcuate and with a central punctiform elevation. M. C., Sydney (R. Brown).

20. *S. eminens*, spec. nov. (Fig. 161, H). Like *S. obovata*, Lesqx., but with narrower ribs, and larger and less distant areoles, each with a slight groove above. M. C., Sydney (R. Brown).

21. *S. Dournaisii*, Brongn. M. C., Joggins (J. W. D.).

22. *S. Knorrii*, Brongn. M. C., Sydney (R. Brown).

Syringodendron, Brongn.

Obscure specimens, referable to a narrow-ribbed species of this genus, occur in the Lower Carboniferous beds at Horton and Onslow.

Stigmaria, Brongn.

Stigmaria ficoides, Brongn. (Fig. 30, *d*). Under this name I place all the roots of *Sigillariæ* occurring in the Carboniferous rocks of Nova Scotia. They belong, without doubt, to the different species of Sigillarioid trees; but it is at present impossible to determine to which; and the specific characters of the *Stigmariæ* themselves are, as might be anticipated, evanescent and unsatisfactory. The varieties which occur in Nova Scotia, discarding mere difference of preservation, may be arranged as follows:—

Var. *a.* Areoles large, distant; bark more or less smooth. This is the most common variety, and extends throughout the Coal formation.

Var. *b.* Areoles large, separated by waving grooves of the bark.

Var. *c.* Similar, but ridges as well as furrows between the areoles; var. *undulata* of Goeppert.

Var. *d.* Areoles small, separated by waving grooves.

Var. *e.* Areoles moderate, in vertical or diagonal furrows separated by ridges; var. *Sigillarioides* of Goeppert.

Var. *f.* Areoles small; bark finely netted with wrinkles or striæ.

Var. *g.* Areoles surrounded by radiating marks, giving a star-like form; var. *Stellata* of Goeppert. The only specimen I have seen was found by Dr Harding in the Lower Carboniferous Coal measures of Horton.

Var. *h.* Areoles small, or obscure and infrequent. Surface covered with fine uneven striæ. My specimens were collected by Mr Brown in the Middle Coal measures at Sydney.

Var. *i.* Areoles narrow, elongate, bark smooth or striate.

Var. *k.* *Alternans*, with areoles in double rows on broad ribs separated by deep furrows. Probably old furrowed roots.

Var. *l.* *Knorroides.* Prominent bosses or ridges instead of areoles. These are imperfectly preserved specimens.

The varieties *a*, *b*, *c*, *e*, *i*, have been seen attached to trunks of *Sigillariæ* of the group distinguished by broad and prominent ribs—*Sigillaria* proper of the above arrangement. *Stigmariæ*, like *Sigillariæ*, are exceedingly abundant in the Middle Coal measures, and are comparatively rare in the Lower Carboniferous and newer Coal formations.

Calamodendron, Brongn.

1. *Calamodendron approximatum*, Brongn. (Fig. 162). This plant is evidently quite distinct from *Calamites* proper. The Calamite-like cast is a pith or internal cavity, surrounded by a thick cylinder of woody tissue consisting of scalariform vessels and woody fibres with one row of round pores; external to this is a bark of cellular and bast tissue. The structure appears to be allied to that of *Sigillaria* and is one of the most common in the beds of bituminous coal. M. C., Sydney (R. Brown); M. C., Joggins, Pictou (J. W. D.); Coal Creek (C. B. Matthew).

2. *C. obscurum*, spec. nov. This is a Calamite-like fragment found in a block of Sydney coal, in the state of mineral charcoal. The external markings are obscure, but the structure is well preserved. It differs from the last in having large ducts with many rows of pores,

or reticulated instead of scalariform vessels. This is perhaps a Calamite. M. C., Sydney (J. W. D.).

CYPERITES, L. and H.

Cyperites —— (?) These elongate linear leaves have two or three ribs, and the central band between the ribs raised above the margin; one species has been seen attached to *Sigillaria scutellata* (Fig. 161, L). The leaves of *Sigillaria elegans* are different, being as broad as the areoles of the stem, and with several parallel veins (Fig. 161, B^1). Middle and Upper coals, everywhere.

ANTHOLITHES, Brongn.

1. *Antholithes Rhabdocarpi*, spec. nov. (Fig. 173, B). Stem short, interruptedly striate, with two rows of crowded ovate fruits, and traces of floral leaves. Fruits half an inch long, striated longitudinally, attached by short peduncles. M. C., Grand Lake (C. F. Hartt).

2. *A. pygmæus*, spec. nov. (Fig. 173, H). Rhachis one-tenth inch thick, rugose; two rows of opposite flowers, each showing four lanceolate striate floral leaves, two outer and two inner. M. C., Joggins (J. W. D.).

3. *A. spinosus*, spec. nov. (Fig. 173, C). Stem one-fourth inch wide, delicately striate, slightly wrinkled longitudinally, as if by pressure. Flowers opposite, of ovate striate leaves or scales, and at base of each a long pointed narrow striate bract or scale. Fruit apparently an ovate striate nut—(*Rhabdocarpus*). Of same type with *A. rhabdocarpi*, but with thicker stem, smaller flowers, and much longer bracts. M. C., Pictou (J. Barnes).

4. *A. squamosus*, spec. nov. (Fig. 173, A). Rhachis thick, coarsely rugose, with two rows of closely placed cones or scaly fruits. U. C., Pictou (J. W. D.).

5. *A.* —— (?), spec. nov. Indistinct, but apparently different from those above described. M. C., Joggins (J. W. D.); Sydney (R. Brown).

TRIGONOCARPUM, Brongn.

1. *Trigonocarpum Hookeri* (Fig. 174), Dawson, Quart. Journ. Geol. Soc., vol. xvii. M. C., Mabou (J. W. D.).

2. *T. Sigillariæ*, spec. nov. Ovate, one quarter inch long; testa smooth, or rugose longitudinally, acuminate, two edged. Found in erect trunks of *Sigillariæ* in large numbers. M. C., Joggins (J. W. D.).

3. *T. intermedium*, spec. nov. (Fig. 173, D). Allied to *T. olivæformis*, but larger and more elongated. M. C., Joggins (J. W. D.).

4. *T. avellanum*, spec. nov. (Fig. 173, F). Allied to *T. ovatum*, L. and H.; three-ribbed, size and form of a filbert. M. C., Joggins (J. W. D.); Sydney (R. Brown).

5. *T. minus*, spec. nov. Half the size of *T. Hookeri*, and similar in form. M. C., Joggins (J. W. D.).

6. *T. rotundum*, spec. nov. Small, round-ovate, slightly pointed. M. C., Joggins (J. W. D.).

7. *T. Nœggerathi*, Brongn. (Fig. 173, E). Newer Coal formation, Pictou (J. W. D.).

RHABDOCARPUS, Goepp. and Bergm.

1. *Rhabdocarpus* —— (?), spec. nov. Ovate acuminate, less than half an inch long. M. C., Joggins (J. W. D.).

2. *R. insignis*, spec. nov. (Fig. 173, G). 1·5 inch long, ovate, smooth, with about seven ribs on one side, and the intervening surface obscurely striate. The nature of this fossil is perhaps doubtful; but if a fruit, it is the largest I have seen in the Coal formation. U. C., Pictou (J. W. D.).

CALAMITES, Suckow.

1. *Calamites Suckovii*, Brongn. (Figs. 39 and 163, A). This species is one of the most common in an erect position. It has verticillate branchlets, with pinnate linear leaflets. M. C., Sydney (R. Brown); Joggins (Lyell; J. W. D.); Grand Lake and Springhill (C. F. Hartt); U. C., Pictou (J. W. D.); Coal Creek (C. B. Matthew).

2. *C. Cistii*, Brongn. (Fig. 163, B). M. C., Joggins (J. W. D.); Sydney (R. Brown); Grand Lake (C. F. Hartt); Bay de Chaleur (Logan); Coal Creek (C. B. Matthew). Often found erect. Its leaves are verticillate, simple linear, striate, apparently one-nerved, and three inches long.

3. *C. cannæformis*, Brongn. M. C., Joggins (Lyell; J. W. D.); Sydney (R. Brown).

4. *C. ramosus*, Artis. Possibly a variety of *C. Suckovii*. M. C., Joggins (J. W. D.); Sydney (R. Brown).

5. *C. Voltzii*, Brongn. (Fig. 37). (*C. irregularis*, L. and H.) M. C., Joggins (J. W. D). Often erect; has large irregular adventitious roots. This species is regarded by Brongniart as probably belonging to *Calamodendron*.

6. *C. dubius*, Artis. M. C., Sydney (R. Brown); Joggins (J. W. D.; Logan); U. C., Pictou (J. W. D.).

7. *C. Nova-Scotica*, spec. nov. M. C., Joggins (J. W. D.). Ribs equal, less than a line wide, striated longitudinally. Joints obscurely marked, and with circular areoles separated by the breadth of three to four ribs. Bark of moderate thickness.

8. *C. nodosus*, Schloth. (Fig. 163, C). This species has long slender branchlets, with close whorls of short rigid leaves. M. C., Sydney (R. Brown); Grand Lake (C. F. Hartt).

9. *C. arenaceus* (?), Jäger. This species is mentioned with doubt in Lyell's list.

EQUISETITES, Sternberg.

Equisetites curta, spec. nov. (Fig. 164). Short thick stems, enlarging upward, and truncate above; joints numerous; sheaths as long as the joints, with unequal acuminate keeled points. Lateral branches or fruit with longer leaf-like points. Has the characters of *Equisetites;* but its affinities are quite uncertain. M. C., Sydney (R. Brown).

ASTEROPHYLLITES, Brongn.

1. *Asterophyllites foliosa*, L. and H. M. C., Joggins (J. W. D.); Sydney (R. Brown). Springhill (*C. F. Hartt*).

2. *A. grandis*, Sternberg (?). The specimens resemble this species, but are not certainly the same. Logan's specimens have terminal spikes of fructification. M. C., Grand Lake (C. F. Hartt); Bay de Chaleur (Logan); Sydney (Bunbury). Springhill (C. F. Hartt).

3. *Asterophyllites*, sp. A species with tubercles (fruit) in the axils is mentioned in Lyell's list as from Sydney. I have not seen it, but have a specimen from Mr Brown similar to *A. tuberculata*, Sternberg, which may be the same.

4. *A. trinervis*, spec. nov. (Fig. 165, A). Main stem smooth, delicately striate, with leaves at the nodes. Branches delicately striate, with numerous whorls of linear nearly straight leaves, 0·5 inch long, twenty or more in a whorl, and showing two lateral nerves in addition to the median nerve. M. C., Sydney (R. Brown).

5. *Asterophyllites* (*Bechera*) *curta*, spec. nov. Stems thin, coarsely ribbed. Internodes about a line long. Nodes with whorls of short linear leaves, nearly at right angles to the stem, which bifurcates at very obtuse angles. M. C., Pictou (J. Barnes, Esq.) This peculiar species is of the type of *A. grandis*, and belongs to the section *Bechera* of Sternberg; plants which, at least in habit of growth, are certainly different from ordinary *Asterophyllites*.

ANNULARIA, Sternberg.

1. *Annularia sphenophylloides*, Zenker (Fig. 165, B). M. C.,

Grand Lake (C. F. Hartt); U. C., Pictou (J. W. D.); Bay de Chaleur (Logan); Sydney (R. Brown).

2. *A. equisetiformis*, L. and H. M. C., Sydney (R. Brown); Pictou (J. W. D.).

SPHENOPHYLLUM, Brongn.

1. *Sphenophyllum emarginatum*, Brongn. M. C., Sydney (R. Brown); Grand Lake (C. F. Hartt); Bay de Chaleur (Logan); Pictou (J. W. D.).

2. *S. longifolium*, Germar. U. C., Pictou (J. W. D.); M. C., Sydney (R. Brown).

3. *S. saxifragifolium*, Sternberg. Elongate much-forked variety, closely allied to *S. bifurcatum*, Lesquereux. Bay de Chaleur (Logan).

4. *S. Schlotheimii*, Brongn. M. C., Sydney (Bunbury).

5. *S. erosum*, L. and H. M. C., Sydney (Bunbury) (Fig. 165, C). The last two species are regarded by Geinitz as varieties of *S. emarginatum*. A specimen of the last-named species in Sir William Logan's collection shows a woody jointed stem like that of *Asterophyllites*, giving off branches at the joints; these again branch and bear whorls of leaves. The stem shows under the microscope a single bundle of reticulated or scalariform vessels like those of some ferns, and also like those of *Tmesipteris*, as figured by Brongniart. This settles the affinities of these plants as being with ferns or with *Lycopodiaceæ*, rather than with *Equisetaceæ*, as at p. 444 above.

PINNULARIA, L. and H.

1. *Pinnularia capillacea*, L. and H. M. C., Sydney (R. Brown).

2. *P. Ramosissima*, spec. nov. (Fig. 165, D). More slender and ramose than the last. M. C., Joggins (J. W. D.).

3. *P. crassa*, spec. nov. Branching like *P. capillacea*, but much stronger and coarser. L. C., Horton (C. F. Hartt). All these are apparently branching fibrous roots, of soft cellular tissue with a thin epidermis and slender vascular axis. Perhaps they are roots of *Asterophyllites*.

Genus NŒGGERATHIA, Sternberg.

1. *Nœggerathia dispar*, spec. nov. (Fig. 73). A remarkable fragment of a leaf, with a petiole nearly three inches long, and a fourth of an inch wide, spreading abruptly into a lamina, one side of which is much broader than the other, and with parallel veins running up directly from the margin as from a marginal rib. It appears to be

doubled in at both edges, and is abruptly broken off. It seems to be a new species; but of what affinities, it is impossible to decide. Bay de Chaleur (Sir W. E. Logan).

2. *N. flabellata*, L. and H. M. C., Sydney (R. Brown).

CYCLOPTERIS, Brongn.

(including *Cyclopteris* proper, and subgenera *Aneimites*, Daws., and *Neuropteris*, Brongn. in part).

1. *Cyclopteris heterophylla*, Goeppert. M. C. and U. C., Joggins (J. W. D.).

2. *C.* (*Aneimites*) *Acadica*, Dawson, Quart. Journ. Geol. Soc., vol. xvii. p. 5 (Fig. 75). Stipe large, striate, branching dichotomously several times. Pinnæ with several broadly obovate pinnules grouped at the end of a slender petiolule, and with dichotomous radiating veins. Fertile pinnæ with recurved petiolules, and borne on the divisions of the main petiole near their origin. This plant might be placed in the genus *Adiantites*, Brongn., but for the fructification, which allies it with such ferns as *Aneimia*. It has a very large frond, the main petiole being sometimes three inches in diameter, and two feet long before branching. Flattened petioles have sometimes been mistaken for *Cordaites* and *Schizopteris*. It is a characteristic plant of the Lower Coal measures. L. C., Horton (C. F. Hartt); Norton Creek, N.B. (G. F. Matthew).

3. *C. oblongifolia*, Goeppert. A little larger and coarser than Goeppert's figure. U. C., Pictou (J. W. D.).

4. *C.* (*Neuropteris*) *obliqua*, Brongn. M. C., Sydney (R. Brown); Grand Lake (C. F. Hartt).

5. *C.* (*? Neuropteris*) *ingens*, L. and H. M. C., Sydney (R. Brown); Grand Lake and Springhill (C. F. Hartt).

6. *C. oblata*, L. and H. M. C., Sydney (R. Brown).

7. *C. fimbriata*, Lesquereux. M. C., Sydney (R. Brown).

8. *C. hispida*, spec. nov. Pinnate; pinnules obovate, diminishing in size towards the point, decurrent on the petiole; veins slender, distant, forking several times; under surface covered with stiff hairs. M. C., Sydney (R. Brown).

9. *C. antiqua*, spec. nov. L. C., (?) Herbert River (J. W. D). Tripinnate; petioles slender; pinnules oblong, obtuse, decurrent on the petiole, not contiguous. Terminal pinnules much elongated; venation simple, divergent. This plant approaches more nearly to the peculiar species of *Cyclopteris* found in the Devonian, than any of the others I have seen in the Carboniferous.

NEUROPTERIS, Brongn.

1. *Neuropteris rarinervis*, Bunbury (Fig. 156, *f*). M. C., Sydney (R. Brown); Grand Lake and Springhill (C. F. Hartt); Bay de Chaleur (Logan).

2. *N. perelegans*, spec. nov. M. C., Sydney (R. Brown). Resembles *N. elegans*, Brongn., but has narrower pinnules, and nerves less oblique to the midrib. The pinnules were thick and leathery, rough or cellular-netted above, and showing the venation only on the underside.

3. *N. cordata*, Brongn. (and var. *angustifolia*). (Fig. 166, B). The ferns referred to this species are identical with *N. hirsuta* of Lesquereux. They abound in the Middle and Upper Coal formations, and have larger pinnules than any of the other ferns. A single terminal pinnule in my collection is five inches long. The surface is always more or less hairy. M. C., Sydney (R. Brown); U. C., Pictou (J. W. D.).

4. *N. Voltzii*, Brongn. A single imperfect specimen like this species, but uncertain. M. C., Pictou (J. W. D.).

5. *N. gigantea*, Sternb. M. C., Sydney (R. Brown); Grand Lake (C. F. Hartt); U. C., Pictou (J. W. D.).

6. *N. flexuosa*, Sternb. M. C., Sydney (R. Brown); Joggins (J. W. D.).

7. *N. heterophylla*, Brongn. M. C., Sydney (R. Brown); U. C., Pictou (J. W. D.).

8. *N. Loshii*, Brongn. Bay de Chaleur (Logan).

9. *N. acutifolia*, Brongn. M. C., Sydney (Lyell's list).

10. *N. conjugata*, Goepp. M. C., Sydney (Brown's list, "Acad. Geol.").

11. *N. attenuata*, L. and H. M. C., Sydney (l. c.).

12. *N. dentata*, Lesq. M. C., Sydney (R. Brown).

13. *N. Soretii* (Brongn.). M. C., Sydney (R. Brown).

14. *N. auriculata*, Brongn. M. C., Sydney (R. Brown).

15. *N. cyclopteroides*, spec. nov. (Fig. 166, F). Pinnate; pinnules contiguous or overlapping, obliquely round-ovate, attached at the lower third of the base; nerves numerous, spreading from the point of attachment. Allied to *N. Villiersi*, Brongn. M. C., Sydney (R. Brown).

ODONTOPTERIS, Brongn.

1. *Odontopteris Schlotheimii*, Brongn. M. C., Sydney (R. Brown); Bay de Chaleur (Logan); U. C., Pictou (J. W. D.).

2. *O. subcuneata*, Bunbury (Fig. 166, A). M. C., Sydney (R. Brown).

DICTYOPTERIS, Gutb.

Dictyopteris obliqua, Bunbury (Fig. 166, D). M. C., Sydney (R. Brown).

LONCHOPTERIS, Brongn.

Lonchopteris tenuis, spec. nov. Pinnate or bipinnate; pinnules contiguous at the base, nearly at right angles to petiole, oblong elongate, obtuse. Network of veins very delicate. Allied to *L. Bricii*, Brongn., but with smaller, more elongate pinnules and finer veins. I suspect this to be a thick-leaved *Pecopteris*, showing a coarse cellular reticulation on the upper surface. M. C., Sydney (R. Brown).

SPHENOPTERIS, Brongn.

1. *Sphenopteris munda*, spec. nov. (Fig. 69). Like *S. Dubuissonii*, Brongn., or *S. irregularis*, Sternberg, in habit; but the pinnules are obovate, decurrent, and few-veined. M. C., Grand Lake and Springhill (C. F. Hartt).

2. *S. hymenophylloides*, Brongn. M. C., Sydney (R. Brown); U. C., Joggins (J. W. D.).

3. *S. latior*, spec. nov. (Fig. 70). Petiole forking at an obtuse angle, slender, tortuous; divisions bipinnate; pinnæ with broad, rounded, confluent pinnules; veins twice forked, with sori in the forks of the veins. In habit like *S. latifolia*, Brongn., *S. Newberryi*, and *S. squamosa*, Lesq. M. C., Grand Lake and Springhill (C. F. Hartt); U. C., Pictou (J. W. D.).

4. *S. decipiens*, Lesquereux. M. C., Sydney (R. Brown).

5. *S. gracilis*, Brongn. M. C., Joggins. (J. W. D.); Grand Lake (C. F. Hartt).

6. *S. artemisiæfolia*, Brongn. M. C. Grand Lake, Springhill (C. F. Hartt); Sydney (R. Brown).

7. *S. Canadensis*, spec. nov. (Fig. 71). General aspect like *S. Hœninghausi*, but secondary pinnules with a margined petiole, and oblong pinnules divided into three to five obtuse points. It is not unlike *S. marginata*, from the Devonian of St. John. Bay de Chaleur (Logan); Sydney? (R. Brown).

8. *S. Lesquereuxii*, Newberry. M. C., Sydney (R. Brown).

9. *S. microloba*, Guttbier. M. C., Sydney (R. Brown).

10. *S. obtusiloba* (?), Brongn. M. C., Bay de Chaleur (Logan).

PHYLLOPTERIS, Brongn.

Phyllopteris antiqua, spec. nov. (Fig. 166, E). Pinnate; petiole thick, woody; pinnules oblong, pointed, attached by the middle of the base; midrib strong, extending to the point, giving off very oblique nerves, which have obliquely pinnate nervules not anastomosing. A remarkable frond, which, if not the type of a new genus, must belong to that above named. M. C., Sydney (R. Brown).

ALETHOPTERIS, Sternberg.

1. *Alethopteris lonchitica*, Sternberg. (Fig. 166, C). M. and U. C., Joggins (J. W. D.); M. C., Sydney (R. Brown); Grand Lake (C. F. Hartt). Very abundant throughout the Middle and Upper Coal formations, and so variable that several species might easily be founded on detached specimens.

2. *A. heterophylla*, L. and H. (Fig. 156, A). L. C., Parrsborough (A. Gesner).

3. *A. Grandini*, Brongn. M. C., Sydney (R. Brown).

4. *A. nervosa*, Brongn. M. C., Sydney (R. Brown); Bay de Chaleur (Logan); U. C., Pictou (J. W. D.).

5. *A. muricata*, Brongn. M. C., Joggins, Bathurst (Lyell); U. C., Pictou (J. W. D.).

6. *A. pteroides*, Brongn. (*A. Brongnartii*, Goeppert). L. or M. C., Bathurst (Lyell's list).

7. *A. Serlii*, Brongn. M. C., Sydney (R. Brown); Bay de Chaleur (Logan); Springhill (C. F. Hartt).

8. *A. grandis*, spec. nov. (Fig. 72). Bipinnate; pinnæ broad, contiguous, united at the base; veins numerous, once forked, not quite at right angles to the midrib. Upper pinnæ having the pinnules confluent so as to give crenate edges. Still higher the apex of the frond shows distant decurrent long pinnules with waved margins. A very large and fine species of the type of *A. Serlii* and *A. Grandini*, but much larger and different in details. Its texture seems to have been membranaceous; and fragments from that part of the frond where the long simple pinnules are passing into the compound ones might be mistaken for an *Odontopteris*. Bay de Chaleur (Logan).

PECOPTERIS, Brongn.

1. *Pecopteris arborescens*, Schloth. Seems to have been an herbaceous species with a very strong petiole. It occurs in an erect position in a sandstone on Wallace River. M. C., Sydney (R. Brown); U. C., Pictou (J. W. D.); Wallace River (Dr Creed).

2. *P. abbreviata*, Brongn. M. C., Sydney (R. Brown); Salmon River, U. C., Pictou (J. W. D.). Very common both in the Upper and Middle Coal formations.

3. *P. rigida*, spec. nov. Similar to *P. arborescens*, but much smaller, and with finer nerves. U. C., Pictou (J. W. D.).

4. *P. unita*, Brongn. Certain pinnules of a frond are sometimes swollen as if covered with fructification below; and in this state they resemble *P. arguta*, Brongn. The sori are seen in other specimens, and are large, round, and covered with an indusium as in *Aspidium*. M. C., Sydney (R. Brown); U. C., Pictou (J. W. D.).

5. *P. plumosa*, Brongn. M. C., Sydney (R. Brown).

6. *P. polymorpha*, Brongn. M. C., Sydney (R. Brown).

7. *P. acuta*, Brongn. M. C., Pictou (J. W. D.).

8. *P. longifolia*, Brongn. In Bunbury's list, from Sydney.

9. *P. tæniopteroides*, Bunbury. M. C., Sydney (R. Brown).

10. *P. cyathea*, Brongn. M. C., Sydney (R. Brown).

11. *P. æqualis*, Brongn. M. C., Sydney (R. Brown).

12. *P. Sillimani*, Brongn. In Lyell's list, from Sydney.

13. *P. villosa*, Brongn. M. C., Pictou (Lyell's list).

14. *P. Bucklandi*, Brongn. M. C., Sydney (Brown's list).

15. *P. oreopteroides*, Brongn. M. C., Sydney (Brown's list).

16. *P. Decurrens*, Lesq. Has pinnules more crowded, decreasing towards the apex, but may be a variety. M. C., Sydney (R. Brown).

17. *P. Pluckenetii*, Sternb. M. C., Sydney (R. Brown).

Beinertia, Goeppert.

Beinertia Goepperti, spec. nov. Bipinnate; pinnæ broad, contignous, obtuse, with thick pinnules. Pinnules rounded above, obovate below. Midrib thick, oblique, dividing above into a tuft of irregular hair-like veins. M. C., Grand Lake (C. F. Hartt); Bay de Chaleur (Logan); U. C., Joggins (J. W. D.).

Hymenophyllites, Goeppert.

Hymenophyllites pentadactyla, spec. nov. In general habit like *Sphenopteris microloba*, Goepp., but with pinnules divided into from four to seven obtuse cuneate lobes, each with one vein. M. C., Sydney (R. Brown).

Palæopteris, Geinitz.

1. *Palæopteris Harttii*, spec. nov. (Fig. 167, C). Stem or leaf-bases transversely wrinkled with delicate lines; scars transversely oval,

slightly appendaged below; vascular scars confluent. Breadth 1·4 in.; length 0·6 in. M. C., Grand Lake, Springhill (C. F. Hartt).

2. *P. Acadica*, spec. nov. (Fig. 167, D). Stem or leaf-bases longitudinally striated; scars transverse, flat above, rounded and bluntly appendaged below; vascular scars in a transverse row. Breadth of scars 0·7 inch; length 0·5 inch. U. C., Pictou (J. W. D.).

CAULOPTERIS, L. and H.

Several small erect stems at the Joggins seem to be trunks of ferns, but are too obscure for description.

PSARONIUS, Cotta.

Trunks of this kind must be rare in the Nova Scotian Coal-fields. A few obscure stems surrounded by cord-like aërial roots have been found, and probably are remains of plants of this genus.

MEGAPHYTON, Artis.

1. *Megaphyton magnificum*, spec. nov. (Fig. 167, A). Stems large, roughly striated longitudinally; scars contiguous, orbicular, deeply sunk, nearly 3 inches in diameter, and each with a bilobate vascular impression 2 inches broad and an inch high. M. C., Joggins (J. W. D.).

2. *M. humile*, spec. nov. Stem 2·5 inches in diameter; leaf-scars prominent, flattened, and broken at the ends, 1 inch wide. Surface of the stem marked with irregular furrows, and invested with a carbonaceous coating. An internal axis, nearly 2 inches in diameter, with a coaly coating, sends off obliquely thick branches to the leaf-scars. This is a very remarkable specimen, and throws much light on the structure of *Megaphyton*. Unfortunately the minute structures are not preserved. M. C., Sydney (R. Brown).

Genus LEPIDODENDRON, Sternberg.

1. *Lepidodendron corrugatum*, Dawson, Quart. Journ. Geol. Soc., vol. xv. (Fig. 168). Areoles elongate ovate, acute at both ends, with a ridge along the middle, terminating in a single elevated vascular scar at the upper end. In certain states the vascular mark appears in the middle of the areole. In young branches the areoles are contiguous and resemble those of *L. elegans*. In old stems they become separated by spaces of longitudinally wrinkled bark; in very old stems these spaces are much wider than the areoles. Leaves linear, 1 inch or more in length, usually reflected, one-nerved. Cones (*Lepidostrobi*) terminal, short, cylindric, with numerous short, acute-triangular scales. Structure of stem:—a central pith with a slender cylinder of scalariform

vessels, exterior to which is a thick cylinder of cellular tissue and bast fibres, and a dense outer bark. Var. *verticillatum* has the areoles arranged in regular decussate whorls instead of spirally. This difference, which might at first sight seem to warrant even a generic distinction, is proved by specimens in my possession to be merely a variety of *phyllotaxis*. This species is eminently characteristic of the Lower Carboniferous Coal measures, and has not yet been found in the Middle Coal formation. Fragments of bark, resembling that of this species, occur in the Coal formation of Bay de Chaleur, along with leafy branches of *Lepidodendron*, which resemble those of this species, though, I believe, distinct. L. C., Horton, etc. (C. F. Hartt; J. W. D.); Norton Creek, etc., New Brunswick (G. F. Matthew).

2. *L. Pictoense*, spec. nov. (Fig. 169, A). Areoles contiguous, prominent, long oval, acuminate, separated in young stems by a narrow line; breadth to length as 1 to 3, or less; lower half obliquely wrinkled, especially at one side. Middle line indistinct. Leaf-scar at upper end of areole, small, triangular, with traces of three vascular points, nearly confluent. Length of areole about 0·5 inch. Leaves contracted at the base, widening slightly, and gradually contracting to a point; ribs three, central distinct, lateral obscure; length 1 inch. Cones borne at the extremities of the smaller branches, oblong, obscurely scaly. In habit of growth this species resembles *L. elegans*, for which imperfect specimens might be mistaken. It is also near to *L. binerve* and *L. patulum*, Bunbury.* It abounds in the Middle Coal measures. M. C., Sydney (R. Brown); Pictou (H. Poole and J. W. D.); Grand Lake (C. F. Hartt).

3. *L. rimosum*, Sternberg (Fig. 169, D). M. C., Sydney (R. Brown); Joggins (J. W. D.).

4. *L. dichotomum*, Sternberg (*L. Sternbergii*, L. and H.). M. C. Sydney (R. Brown); Joggins (J. W. D.); L. C., Horton (J. W. D.).

5. *L. decurtatum*, spec. nov. (Fig. 170, A). Areoles approximate or separated by a shallow furrow, rhombic ovate, obliquely acuminate below, nearly as broad as long, wrinkled transversely, especially on the middle line, which appears tuberculated; vascular scar rhombic, twice as broad as long, with three approximate vascular points. In some flattened specimens the line separating the areoles is indistinct, and the scars appear on a transversely wrinkled surface without distinct areoles. M. C., Pictou (J. W. D.).

6. *L. undulatum*, Sternberg. (Fig. 169, E). Possibly several species

* In certain states of preservation, the lateral ribs of the leaves become obsolete; and in others the central disappears, in which state the resemblance to *L. binerve* is very close.

are included under this name; but they cannot be separated at present. M. C., Sydney (R. Brown); Joggins and Pictou (J. W. D.); U. C, Joggins (J. W. D.).

7. *L. dilatatum*, Lindley and Hutton. M. C., Joggins (J. W. D.).

8. *L.*, sp. like *tetragonum*, Goepp. Obscurely marked, but a distinct species, unless an imperfectly preserved variety of *L. tetragonum*. The areoles are square, with a rhombic scar at the upper corner of each. L. C., Horton (J. W. D.).

9. *L. binerve*, Bunbury. M. C., Sydney (R. Brown).

10. *L. tumidum*, Bunbury. I think it probable that this species belongs to the genus *Lepidophloios;* but I have not seen a specimen. M. C., Sydney (R. Brown).

11. *L. gracile*, Brongn. In Brown's list in "Acadian Geology." Probably a variety of the next. M. C., Sydney (R. Brown).

12. *L. elegans*, Brongn. In Bunbury and Brown's lists. M. C. Sydney (R. Brown).

13. *L. plumarium*, L. and H. M. C., Sydney (in Brown's list).

14. *L. selaginoides*, Sternb. M. C., Sydney (in Brown's list).

15. *L. Harcourtii* (Witham). M. C., Sydney (in Brown's list).

16. *L. clypeatum* (?), Lesqx. M. C., Sydney (R. Brown); U. C., Joggins (J. W. D.).

17. *L. aculeatum*, Sternberg. M. C., Sydney (R. Brown).

18. *L. plicatum*, spec. nov. (Fig. 169, C). Leaf-areoles much elongated; breadth to length as 1 to 5 or 6, tranversely rugose; central line indistinct. Leaf-scar rhombic, with three vascular points; scars in old stems separated by rugose bark, and somewhat elongate. M. C., Pictou (J. W. D.).

19. *L. personatum*, spec. nov. (Fig. 169, B). Areoles ovate acuminate; breadth to length as 1 to 3 or 4, contiguous in young stems; central line distinct; lower part of areole with transverse lines. Leaf-scars ovate, with two marks above and two below; leaves slender, 1 inch long, one-nerved. M. C., Sydney (R. Brown).

Halonia, L. and H.

Halonia, sp. A specimen probably referable to this genus from Grand Lake, in the collection of C. F. Hartt.

Lepidostrobus, Brongn.

1. *Lepidostrobus variabilis*, L. and H. The most common species. M. C., Sydney (R. Brown); Pictou and Joggins (J. W. D.).

2. *L. squamosus*, spec. nov. (Fig. 171, E.) 2 to 3 inches long, 1 inch thick; scales large, broadly trigonal, acute. Allied to *L. trigonolepis*, but larger. Probably a cone of *Lepidophloios*. M. C., Grand Lake (C. F. Hartt).

3. *L. longifolius*, spec. nov. Long-leaved, like *Lepidodendron longifolium*, L. and H. M. C., Joggins (J. W. D.).

4. *Lepidostrobus*, sp. Acute trigonal leaves, small. M. C., Joggins (J. W. D.).

5. *Lepidostrobus*, sp. Round, with obscure scales and remains of long leaves. L. C., Horton (J. W. D.).

6. *L. Trigonolepis*, Bunbury. M. C., Sydney (R. Brown).

LEPIDOPHYLLUM, Brongn.

1. *Lepidophyllum lanceolatum*, L. and H. M. C., Joggins; U. C., Pictou (J. W. D.).

2. *L. Trinerve* (?), L. and H. Two-nerved or three-nerved, like *L. trinerve*, L. and H., but narrower. Both the above are parts of *Lepidostrobi*. U. C., Joggins (J. W. D.).

3. *L. Majus* (?), Brongn. M. C., Sydney (R. Brown).

4. *Lepidophyllum*, sp. Broad ovate, short, pointed, one-nerved, half an inch long. U. C., Pictou.

5. *L. intermedium*, L. and H. M. C., Sydney (R. Brown's list).

Halonia, *Lepidostrobus* and *Lepidophyllum*, including only parts of *Lepidodendron* and *Lepidophloios*, are to be regarded as merely provisional genera.

LEPIDOPHLOIOS, Sternberg.

1. *Lepidophloios Acadianus*, spec. nov. (Fig. 171). Leaf-bases broadly rhombic, or in old stems regularly rhombic, prominent, ascending, terminated by very broad rhombic scars having a central point and two lateral obscure points. Outer bark laminated or scaly. Surface of inner bark with single points or depressions. Leaves long, linear, with a strong keel on one side, five inches or more in length. Cone-scars sparsely scattered on thick branches, either in two rows or spirally, both modes being sometimes seen on the same branch. Scalariform axis scarcely an inch in diameter in a stem five inches thick. Fruit, an ovate strobile with numerous acute scales covering small globular spore-cases. This species is closely allied to *Ulodendron majus* and *Lepidophloios laricinus*, and presents numerous varieties of marking. M. C., Joggins, Salmon River, Pictou (J. W. D.); Sydney (R. Brown).

2. *L. prominulus*, spec. nov. Leaf-bases rhombic, pyramidal,

somewhat wrinkled at the sides, truncated by regularly rhombic scars, each with three approximate vascular points. M. C., Joggins (J. W. D.).

3. *L. parvus*, spec. nov. (Fig. 170, G). Leaf-bases rhombic, small, with rhombic scars broader than long; vascular points obscure; leaves linear, acute, three inches or more in length, with a keel and two faint lateral ribs. Cones large, sessile. U. C., Pictou; M. C., Joggins (J. W. D.); M. C., Sydney (R. Brown).

4. *L. platystigma*, spec. nov. (Fig. 170, E). Leaf-bases rhombic, broader than long, little prominent; scars rhombic, oval, acuminate, slightly emarginate above; vascular points two, approximate or confluent. M. C., Sydney (R. Brown); Joggins (J. W. D.).

5. *L. tetragonus*, spec. nov. (Fig. 170, D). Leaf-bases square, furrowed on the sides; leaf-scar central, with apparently a single central vascular point. M. C., Joggins (J. W. D.).

Diplotegium, Corda.

Diplotegium retusum, spec. nov. (Fig. 172, B). The fragments referable to plants of this genus are imperfect and obscure. The most distinct show leaf-bases ascending obliquely, and terminating by a retuse end with a papilla in the notch. Some less distinct fragments may possibly be imperfectly preserved specimens of *Lepidodendron* or *Lepidophloios*. M. C., Joggins (J. W. D.).

Knorria.

Nearly all the plants referred to this genus in the Carboniferous rocks are, as Goeppert has shown, imperfectly preserved stems of *Lepidodendron*. In the Lower Coal formation many such *Knorria* forms are afforded by *L. corrugatum*.

Knorria Sellonii, Sternberg. This appears different from the ordinary *Knorriæ;* its supposed leaves may be aërial roots. It has a large pith-cylinder with very distant tabular floors, like *Sternbergia*. M. C., Sydney (R. Brown).

Cordaites, Unger. (Pychnophyllum, Brongn.).

1. *Cordaites borassifolia*, Corda (Fig. 172, A). M. C., Pictou (H. Poole); Grand Lake and Springhill (C. F. Hartt); Sydney (R. Brown); Joggins, Onslow (J. W. D.); Bay de Chaleur (Logan). Very abundant in the Middle Coal formation.

2. *C. simplex*, spec. nov. Leaves similar to the last in size and form, but with simple, equal, parallel nerves. It may be a variety, but is characteristic of the Upper Coal formation. M. C., Grand River (C. F. Hartt); U. C., Pictou (J. W. D.).

CARDIOCARPUM, Brongn.

1. *Cardiocarpum fluitans*, spec. nov. (Fig. 173, I). Oval; apex entire or notched; surface slightly rugose; nucleus round ovate, acuminate, pitted on the surface, with a raised mesial line. M. C., Joggins (J. W. D.).

2. *C. bisectum*, spec. nov. (Fig. 173, K). Nucleus as in the last species, but striate; margin widely notched at apex, and more narrowly notched below. M. C., Grand Lake, Springhill (C. F. Hartt).

3. *Cardiocarpum*, sp. like *C. marginatum*. M. C., Joggins (J.W.D.).

4. *Cardiocarpum*, sp. allied to *C. latum*, Newberry. M. C., Pictou (H. Poole). These *Cardiocarpa* are excessively abundant in the roofs of some coal seams; and the typical ones must have been samaras or winged nutlets. They must have belonged to phænogamous plants, and certainly are not the fruits of *Lepidodendron*, though some of the spore-cases of this genus have been described as *Cardiocarpa*. These I propose to place under the provisional genus *Sporangites*.

SPORANGITES, Dawson.

1. *Sporangites papillata*, spec. nov. (Fig. 173, L). I propose the provisional generic name of *Sporangites* for spores or spore-cases of *Lepidodendron*, *Calamites*, and similar plants, not referred to the species to which they belong. The present species is round, about one inch in diameter, and covered with minute raised papillæ or spines. It abounds in the roof of several of the shaly coals in the Joggins section, and especially in one in group 19 of that section. M. C., Joggins (J. W. D.).

2. *S. glabra*, spec. nov. (Fig. 168, F). About the size of a mustard-seed, round and smooth. Exceedingly abundant in the Lower Carboniferous Coal measures of Horton Bluff, with *Lepidodendron corrugatum*, to which it probably belongs. A similar spore-case, possibly of another species of *Lepidodendron*, occurs rarely in the Middle Coal formation at the Joggins.

STERNBERGIA, Artis.

This provisional genus includes the piths of *Dadoxylon*, *Sigillaria*, and other plants, usually preserved as casts in sandstone, retaining more or less perfectly the transverse partitions into which the pith-cylinders of many coal formation trees became divided in the process of growth. These fossils are most abundant in the Upper Coal formation, but occur also in the Middle Coal formation. The following varieties may be distinguished:—

(*a*.) Var. *approximata*, with fine uniform transverse wrinkles. This is usually invested with a thin coating of structureless coal.

(*b.*) Var. *angularis* (Fig. 160), with coarser and more angular transverse wrinkles. This is the character of the pith of *Dadoxylon.*

(*c.*) Var. *distans*, usually of small size, and with distant and irregular wrinkles. This is sometimes invested with wood having the structure of *Calamodendron*, and perhaps is not generically distinct from *C. approximatum.*

(*d.*) Var. *obscura*, with distinct and distant transverse wrinkles, but not strongly marked on the surface. This is the character of the pith-cylinders of *Sigillaria* and *Lepidophloios.*

ENDOGENITES, L. and H.

Many sandstone-casts, answering to the character of the plants described under this name by Lindley, occur in the Upper Coal formation. They are sometimes three inches in diameter, and several feet in length, irregularly striated longitudinally, and invested with coaly matter. Sometimes they show transverse striation in parts of their length. I believe they are casts of pith-cylinders of the nature of *Sternbergia*, and probably of Sigillarioid trees.

SOLENITES, L. and H.

Plants of this kind are found in the sandstones of the Upper Coal formation of the Joggins.

For all the specimens noticed in the above list as collected by Sir W. E. Logan, Richard Brown, Esq., of Sydney, Cape Breton, Henry Poole, Esq., of Glace Bay, C.B., and G. F. and C. B. Matthew and C. F. Hartt, Esqs., St John, New Brunswick, I am indebted to the kindness of these gentlemen. To Mr Brown especially I am under great obligations for his liberality in placing at my disposal his large and valuable collection of the plants of the Cape Breton Coal-field.

Summary.

1. Of 196 nominal species in the list, probably 44 may be rejected as founded merely on parts of plants, leaving about 152 true species.

2. Of these, on comparison with the lists of Unger, Morris, and Lesquereux, 92 seem to be common to Nova Scotia and to Europe, and 59 to Nova Scotia and the United States. Most of these last are common to Europe and the United States. There are about 54 species peculiar, in so far as known, to Nova Scotia, though there can be little doubt that several of these will be found elsewhere. It would thus appear that the coal flora of Nova Scotia is more closely related to that of Europe than to that of the United States, a curious circumstance in connexion with the similar relationship of the marine fauna of the period; but additional information may modify this view.

3. The greater part of the species have their head-quarters in the Middle Coal formation, and scarcely any species appear in the Upper Coal formation that are not also found in the former. The Lower Coal formation, on the other hand, seems to have a few peculiar species not found at higher levels.

4. The characteristic species of the Lower Coal formation are *Lepidodendron corrugatum* and *Cyclopteris Acadica*, both of which seem to be widely distributed at or near this horizon in Eastern America, while neither has yet been recognised in the true or Middle Coal measures. In the Upper Coal formation *Calamites Suckovii*, *Annularia sphenophylloides*, *Sphenophyllum emarginatum*, *Cordaites simplex*, *Alethopteris nervosa*, *muricata*, *etc.*, *Pecopteris arborescens*, *P. abbreviata*, *P. rigida*, *Neuropteris cordata*, *Dadoxylon materiarum*, *Lepidophloios parvus*, *Sigillaria scutellata*, are characteristic plants, though not confined to this group.

5. In the Middle Coal formation and in the central part of it, near the greater coal seams, occur the large majority of the species of *Sigillaria*, *Calamites*, *Lepidodendron*, and *Ferns;* some of the species ranging from the Millstone-grit into the Upper Coal formation, while others seem to be more narrowly limited. It is to be observed, however, that, as we leave the central part of the system, the total number of species diminishes both above and below, and that it is only in those beds which hold large numbers of plants *in situ* or nearly so, that we can expect to find a great variety of species, and especially the more delicate and perishable organisms.

It is also quite observable in the Joggins section, that while some beds, in the same part of the system, supported *Sigillariæ*, others carried *Calamites*, others mixtures of these with other plants; so that differences of soil, moisture, etc., frequently cause neighbouring beds to be more dissimilar in their fossil contents than others much more widely separated. These local and temporary differences must always have occurred in the deposition of the coal measures, and should not be confounded with those general changes which are connected with lapse of time.

Additional Note on Vegetable Structures in Coal.

In the foregoing pages reference has frequently been made to the existence of distinct vegetable structures in coal; and any ordinary observer may satisfy himself of this by closely inspecting the surfaces of a lump of the mineral with the aid of a bright light and a magnifying glass. But the microscope reveals a world of wonderful tissues in coal, as perfect as if they had only yesterday formed parts of living plants; and as I have devoted many hours of patient labour to the

investigation of these structures, I may here notice very shortly methods by which my results have been obtained, more particul in the case of the mineral charcoal.

In examining the mineral charcoal, I have, after many trials, adop the following process of preparation:—Specimens were selected c taining the tissues of only a single plant. Fragments or portion stems of this character can be obtained by careful manipulation f most coals. They were placed in marked test-tubes, and treated v strong nitric acid, in which they were heated to the boiling-po and kept in that condition so long as dense fumes of nitrous acid w disengaged, or until, on looking through the tube, the material co be seen to have a brown colour and a certain degree of transparen In many cases, boiling in this manner for a short time is sufficien render the fibres flexible, and as transparent as slices of recent w when slightly charred. When ready for examination, the char was allowed to settle, and repeatedly washed with pure water be removing it from the tube. It was then examined in water, v powers of from 50 to 300 diameters, drawings of the structures served being made with a camera; and when it appeared desira specimens were put up in balsam for further examination. S refractory specimens were found to require alternate washing boiling in hydrochloric and nitric acids before their structures co be made out; but in the preparation of more than four hundred sp mens from various kinds of coal I have scarcely met with any t resisted all these processes.*

I may observe here that the object is not to decarbonize the and obtain what has been termed a siliceous skeleton. The cha effected consists in the removal of bituminous matter, which is dized and dissolved by the acid, and of mineral matters, especiall the sulphuret of iron, which is one of the principal causes of brittleness and opacity of the crude mineral charcoal. The prepa material is nearly pure carbon, burning without flame and leav scarcely any ashes. It represents the cell-wall and its ligneous lini or perhaps in some cases only the latter, in a state of perfect integr appearing under the highest powers quite smooth and continu and with all its minute markings in excellent preservation. methods of incineration of the charcoal and of polishing its fin portions I have found to be, in comparison with the nitric acid proc of little value. The first gives no adequate idea of the real chara of the tissues. The second gives merely a rude outline of the m minute markings, and is chiefly valuable as affording cross-secti

* This nitric acid process is, I believe, nearly the same with that recommende Goeppert and Morris.

and a better view of the general arrangement of the tissues than can be obtained from the shreds of woody matter resulting from the process above described.

It is further necessary to state that, to compare specimens of coal with the structures of mineralized plants from the accompanying beds, it is not sufficient to have slices of the latter. It is necessary also to have specimens prepared by removing the mineral matter by an acid. Most of the coal fossils showing structure are mineralized by the carbonates of lime and iron; and on removing these, the cell-walls will be found intact and sometimes apparently not even carbonized. Diluted hydrochloric acid suffices for this; and structures by no means to be found in the comparatively rude slices prepared by the lapidary can be distinguished in these isolated cells. Pyritous fossils, so intractable as slices, can usually be resolved by the treatment with nitric acid, though in some cases they require a preliminary roasting, or, what is better, exposure to the weather until the pyrites begins to crumble.

The observer using the above method will find many vegetable fibres showing no markings. These are usually bast fibres. He will see others with one row of round pores (uniporous), or with distant round pores scattered irregularly (rariporous), or with several rows of alternate simple or bordered pores (multiporous). These are tissues of *Sigillaria* and *Calamodendron*, except some large vessels of the last mentioned type, which belong to *Calamites*. With the porous tissues he will often find slender scalariform vessels, or rather *cells with transverse pores*, which also belong to *Sigillaria* and *Calamodendron*, and are very different from the large coarse scalariform vessels of *Lepidodendron* and its allies, and of *Stigmaria*. The ducts of ferns have been already referred to. Some of these varieties of mineral charcoal afford very beautiful microscopic objects.

Note on the Myriapods of the Coal Formation.

The following has been communicated to me by Mr Scudder, since the printing of the notice of these creatures at page 385, *supra*:—

"The specimens of Myriapods discovered by Dr Dawson in the Sigillarian stumps of the Coal formation of Nova Scotia, belong to two genera; in one, *Xylobius*, Daw., cross sutures divide the segments into numerous fragments, in a manner wholly unknown among living Myriapoda; in the other, which we may call *Archiulus*, the segments are simple. Of the former genus, I have discovered no less than four species among the fragments which Dr Dawson has permitted me to examine. For one the name of *X. sigillariæ*, Daw., may be retained; the illustrations (Fig. 151, *a*, *c*, p. 385) probably

belong to this species. It is distinguished from the others in having all the fragments of which each segment is composed more than twice as broad as long, and the upper edges of the fragments somewhat raised. The segments themselves are about 1-20th of an inch long, slightly convex, with the anterior and posterior edges slightly and equally raised at the suture. Another species, closely allied to this, may be called *X. similis*. On different parts of the body, and even in adjoining segments, the fragments composing the segments vary in form from an oblong half as long (*i.e.*, down the segment) as broad to a square; some are even a little longer than broad. The segments vary in length from 1-25th to 1-30th of an inch, are slightly convex, and apparently have their front and hind edges turned up as in *X. sigillariæ*. To a third species I have applied the name of *X. fractus*: here the fragments are square, the segments are not more than 1-40th of an inch in length, although the insect is as large as *X. sigillariæ;* there seems to be another characteristic in a distinct dorsal furrow. The last species, which we may well name *X. Dawsoni*, is again a larger one: the segments measure from 1-20th to 1-30th of an inch in length; one of them is depicted in Fig. 59, in the Air-breathers. These segments, which are broken up into squarish or transversely oblong fragments, are very differently shaped from those of the other species, the posterior third being elevated into a prominent rounded ridge, upon the falling slope of which the suture of the succeeding segment occurs; the anterior two-thirds of the segment is concave, with a more gradual curve.

"The second genus, *Archiulus*, has but a single species, which, from its resemblance to the other genus, and especially to the last mentioned species, may be named *A. xylobioides*. The segments are shaped almost exactly as in *X. Dawsoni*, but are never broken up into fragments; the segments are about 1-25th of an inch in length. Fig. 151, *b*, p. 385, probably refers to this species."

Should these interesting conclusions be confirmed by Mr Scudder's subsequent investigations, which he proposes to embody in a separate paper, they will show that the group of Myriapods must have been represented by numerous vegetable-feeding species in the Coal period —a result not surprising, when we consider the vast amount of food for such creatures which must have existed in the Carboniferous swamps.

CHAPTER XXI.

THE DEVONIAN PERIOD.

LOWER DEVONIAN OF NOVA SCOTIA.—DEVONIAN OF SOUTHERN NEW BRUNSWICK.—SECTION OF "FERN LEDGES."—USEFUL MINERALS.—CRUSTACEANS AND INSECTS.

THE growth of geological knowledge in Nova Scotia and New Brunswick is in nothing more marked than in the fact that, in 1855, two chapters of Acadian Geology, and those somewhat meagre, sufficed for all the rocks older than the Carboniferous, while now the quantity of matter on these rocks will be more than doubled, and it will be necessary to subdivide them into several series.

In the present chapter I propose to describe the group of rocks immediately under the Carboniferous system, that to which the name Devonian has been given by the English geologists, and which is represented in the United States by the formations from the Catskill or Old Red Sandstone to the Oriskany Sandstone inclusive. I may remark that the controversy which has been raised by Mr Jukes, as to the use of the term Devonian in England, in no respect affects the questions we have to discuss, since whatever views may be entertained respecting the rocks known as Devonian in Devonshire and in Ireland, in America the existence of a great mass of sediment, characterized by a distinct fauna and flora, between the Carboniferous and Upper Silurian, is a fact which cannot be set aside. It is also to be observed that in the Acadian Provinces, in passing downward from the Carboniferous to the Devonian we constantly find unconformability, and that there is ample evidence that the great masses and dikes of intrusive granite which in Nova Scotia penetrate all the rocks older than the Carboniferous belong to the close of the Devonian period.

I had to remark in regard to the Carboniferous period that a well-marked difference in the deposits could be observed in the regions east and west of the Alleghany mountains. A similar difference exists in the Devonian. Beds of oceanic character are much less developed in the Acadian region than they are in New York and

farther west. More especially the thick limestones of the latter districts are not represented, and there is a greater prevalence of sandy and argillaceous deposits, often with fossil plants. Minor differences exist in the Acadian Provinces themselves. In Nova Scotia only the lower members of the system have been distinctly recognised, though there are indications of the upper members. In New Brunswick the newer portion of the Devonian seems most largely developed, and is remarkably rich in fossil plants.

I shall first notice the Lower Devonian rocks of Nictaux and its vicinity in Western Nova Scotia, and then, crossing the Bay of Fundy, describe the rich plant-bearing beds in the vicinity of St John, New Brunswick.

Devonian of Nova Scotia.

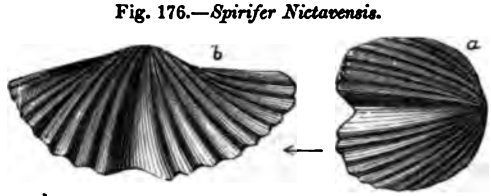
In Nova Scotia the rocks older than the Carboniferous system have all undergone more or less alteration and disturbance. This, with the imperfect preservation of their fossils and their inland position, renders the working up of their details of structure very difficult. Large tracts of country thus remain in a state of uncertainty, their rocks being manifestly older than the Carboniferous, but yet otherwise of uncertain age. In the case of the Devonian, the only place in which it has been clearly made out as distinct from the Silurian, is the belt of hilly country extending along the south side of the Annapolis valley. Here, in the section of the Nictaux River, the first old rocks that are seen to emerge from beneath the New Red Sandstone of the low country, are fine-grained slates, which I shall describe in the sequel as Upper Silurian. Their strike is N. 30° to 60° E., and their dip to the S. E. at an angle of 72°. Interstratified with these are hard and coarse beds, some of them having a trappean aspect. In following these rocks to the S. E., or in ascending order, they assume the aspect of the New Canaan beds; but I could find no fossils except in loose pieces of coarse limestone, and these have the aspect of the Upper Arisaig series, or newest Silurian of the eastern part of Nova Scotia. In these, and in some specimens recently obtained by Mr Hartt, I observe *Orthoceras elegantulum*, *Bucania trilobita*, *Cornulites flexuosus*, *Spirifer rugæcosta?* and apparently *Chonetes Nova-Scotica*, with a large *Orthoceras*, and several other shells not as yet seen elsewhere,—all Upper Silurian. These fossils appear to indicate that there is in this region a continuance of beds of the upper Arisaig series nearly to the base of the Devonian rocks next to be noticed.

After a space of nearly a mile, which may represent a great thickness of unseen beds, we reach a band of highly fossiliferous peroxide of

iron, with dark coloured coarse slates, dipping S. 30° E. at a very high angle. The iron ore is from 3 to 4½ feet in thickness. The fossils of the ironstone and the accompanying beds, as far as they can be identified, are *Spirifer arenosus*, *Strophodonta magnifica*, *Atrypa unguiformis*, *Strophomena depressa*, and species of *Avicula*, *Bellerophon*, *Favosites*, and *Zaphrentis*, etc. These Professor Hall compares with the fauna of the Oriskany sandstone; and they seem to give indubitable testimony that the Nictaux iron ore is of Lower Devonian age. The most abundant fossil is a *Spirifer* as yet not identified with any described species, but eminently characteristic of the Nictaux deposits. It is usually seen only in the state of casts, and often also strangely distorted by the slaty structure of the beds. The specimens least distorted may be described as follows:—General form, semi-circular tending to semi-oval, convexity moderate; hinge-line about equal to width of shell; a rounded mesial sinus and elevation with about ten sub-angular plications on each side; a few sharp growth ridges at the margin of the larger valves. Average diameter about one inch; mesial sinus equal in width to about three plications. I shall call this species, in the meantime, *S. Nictavensis*.

I figure two distorted specimens (Fig. 176), to show the remarkable differences of form produced in this way. The original form is intermediate.

Fig. 176.—*Spirifer Nictavensis*.

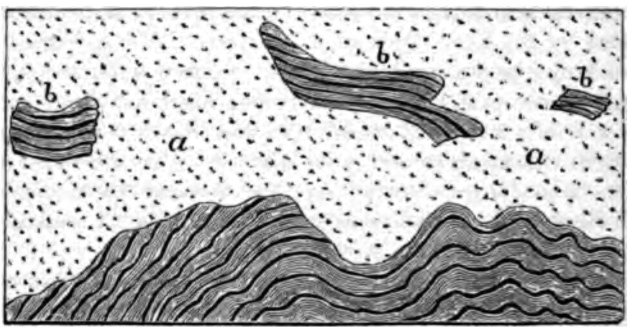


(*a*) Shortened, and (*b*) lengthened, by distortion, in the direction of the arrow.

To the southward of the ore, the country exhibits a succession of ridges of slate holding similar fossils, and probably representing a thick series of Devonian beds, though it is quite possible that some of them may be repeated by faults or folds. Farther to the south these slates are associated with bands of crystalline greenstone and quartz rock, and are then interrupted by a great mass of white granite, which extends far into the interior and separates these beds from the similar, but non-fossiliferous, rocks on the inner side of the metamorphic band of the Atlantic coast. The Devonian beds appear to dip into the granite, which is intrusive, and alters the slates near the junction into gneissoid rock holding garnets. The granite sends veins into the slates, and near the junction contains numerous angular fragments of altered slate.

This junction is of great interest, as showing the gradual alteration of slaty beds holding fossils into gneissose rock with garnets, within the distance in some places of a few hundred feet. It is observable also, that while the gneiss graduates into the slate it does not pass imperceptibly into the granite, but presents a distinct line of separation, marking the limit of the Plutonic and Metamorphic rocks, and indicating that the granite was truly a heated mass intruded among the aqueous deposits (Fig. 177). Farther, as the granite is itself of

Fig. 177.—*Junction of Granite and Devonian Slate, Nictaux.*



(*a*) Granite. (*b*) Slate with gneissose character, in fragments imbedded in the granite.

Devonian age, we learn that no great interval of geological time elapsed between the deposition and the metamorphism of the beds. Again, as the granite cannot be a superficial or surface rock, there must have been a mass of upper Devonian rocks swept away by denudation to expose the beds as at present. Lastly, though the beds are inclined at high angles, they run against the granite in their line of strike in such a manner as to show that it cuts quietly through them, without any great evidence of mechanical disturbance in connexion with its eruption, and it would appear that the general direction of dip is toward the granitic mass, as if the Devonian and Upper Silurian beds had sunk into a caldron of molten granite. Further exploration of the country southward of Nictaux will be necessary before we understand in detail the relation of the Devonian rocks to the great masses of granite which appear in this direction.

Westward of the Nictaux River, the granite abruptly crosses the line of strike of the slates, and extends quite to their northern border, cutting them off in the manner of a huge dike from their continuation about ten miles further westward. The beds of slate in running against this great dike of granite, change in strike from south-west to

west, near the junction, and become slightly contorted and altered into gneiss, and filled with granite veins; but in some places they retain traces of their fossils to within 200 yards of the granite. The intrusion of this great mass of granite without material disturbance of the strike of the slates conveys the impression that it has melted quietly through the stratified deposits, or that these have been locally crystallized into granite *in situ*.

At Moose River the iron ore and its associated beds recur on the western side of the granite before mentioned, but in a state of greater metamorphism than at Nictaux. The iron is here in the state of magnetic ore, but still holds fossil shells of the same species with those of Nictaux.

Still farther westward, at Bear River, near the bridge by which the main road crosses this stream, beds equivalent to those of Nictaux occur with a profusion of fossils. The iron ore is not seen, but there are highly fossiliferous slates and coarse arenaceous limestone, and a bed of gray sandstone with numerous indistinct impressions apparently of plants. In addition to several of the fossils found at Nictaux, these beds afford *Tentaculites*, an *Atrypa*, apparently identical with an undescribed species very characteristic of the Devonian sandstones of Gaspé, and a coral which Mr Billings identifies with the *Pleurodictyum problematicum*, Goldfuss, a form which occurs in the lower Devonian in England, and on the continent of Europe.

Westward of Bear River, rocks resembling in mineral character those previously described, and probably of Devonian and Upper Silurian age, extend with similar strike, but in an altered condition, and in so far as I have been able to ascertain, destitute of fossils, quite to the western extremity of the peninsula, where they turn more to the southward, and are as I suppose, repeated by a sharp synclinal fold, after which they are succeeded by the Atlantic coast series, of lower Silurian date, and consisting of quartzite and clay slate, with chlorite and hornblende slates at Yarmouth and its vicinity, and further to the S. E. of mica slate and gneiss.

I cannot certainly indicate the Devonian system in other parts of Nova Scotia. There are, however, in various places, at the margin of the Carboniferous areas, or projecting through these beds, rocks which may be Devonian, though, not having afforded characteristic fossils, their age must remain doubtful, as they might possibly prove to be altered members of the Lower Carboniferous or rocks of Silurian date. They are usually hard gray or purplish sandstone or quartzites, associated with gray or purplish slates or shales. Such rocks occur in the flanks of the Cobequid Hills, in the vicinity of Salmon River, and

in the hills of Mount Thom and Mount Dalhousie. They are also found in the hilly country of Pictou and Antigonish; and the remarkable mass which seems to project through the Coal formation between the East and Middle Rivers of Pictou is of this character. Its rocks do not resemble those of the Silurian series, and they abound in obscure remains, evidently of land plants, which, though not certainly determinable, resemble those of the Devonian rather than those of the Carboniferous.

Mr J. Campbell of Halifax seems to have been the first to observe these rocks; and I had the pleasure of examining them in his company in 1866. The fossils which I obtained are stipes of ferns, apparently of two species: a *Pinnularia*, and branching stems much resembling those of *Psilophyton*, a characteristic Devonian genus. There were also fragments of carbonized and pyritized wood, but not sufficiently perfect to show structure. These plants were contained in a hard gray altered sandstone or quartzite, underlying unconformably a Carboniferous conglomerate in Bear Brook, near the Middle River. I have received a specimen of laminated limestone, not fossiliferous, from this vicinity, and which probably belongs to the present series.

These somewhat unpromising rocks would afford a rich field to any geological observer who could enjoy the work of unravelling stratigraphical intricacies; and there is no reason to despair of their affording fossil remains were they explored with sufficient thoroughness. More especially the rich Devonian flora of St John, New Brunswick, encourages us to hope for similar discoveries of fossil plants in Nova Scotia. Collectors should keep this in view, more especially as, without attention, such plants might be confounded with those of the Carboniferous rocks.

Devonian of New Brunswick.

The belt of partially metamorphosed rocks rising from beneath the Carboniferous on the southern coast of New Brunswick, was mapped in my first edition as Upper Silurian or Devonian, but without any certain evidence as to its age, other than its manifestly underlying the Carboniferous, and resembling somewhat in mineral character the rocks of Upper Silurian and Devonian age in Nova Scotia. The first fossil from these rocks ever seen by me was a specimen of *Calamites*, brought by the late Professor Robb of the University of New Brunswick to Montreal when on a visit to Canada in 1857. Professor Robb, impressed with the importance of the occurrence of vegetable fossils in these beds, proposed to devote some time to their study; but his lamented decease prevented this intention from being

carried into effect. The subject was, however, followed out by several gentlemen of St John engaged in geological studies, and more particularly by Mr G. F. Matthew and Mr C. F. Hartt, from whom I received the specimens described in my paper on the Pre-Carboniferous Flora of Eastern America in 1861, and with whom I had subsequently an opportunity of exploring the localities of the fossils. From these gentlemen I also obtained the further material published in my Flora of the Devonian Period, in 1862.* Mr Matthew subsequently published a detailed account of the stratigraphical relations of the beds,† and Mr Hartt has since collected largely from the most productive localities for the Natural History Society of St John, which has liberally placed its collections in my hands. Many additional facts in relation to these beds have also been published in the Report of Professor Bailey on the Geology of Southern New Brunswick. With the aid of these materials, I shall endeavour to give an account of this interesting formation, and shall then notice in some detail its fossils.

The Devonian series of the vicinity of St John is well exposed in the shore of Courtnay Bay, and also in the vicinity of Carlton. The red conglomerates, which here form the base of the Carboniferous, rest on it unconformably, and it is itself underlaid by the St John slates, a group of Lower Silurian age.

The succession of beds seen in the Courtnay Bay and St John sections is thus given in my paper of 1862. The thicknesses stated are to be regarded as merely rough estimates, made up partly from Mr Matthew's observations, and partly from my own. The names are those given by Mr Matthew and Professor Bailey:—

Carboniferous System.

	Feet.
Coarse red conglomerate, with pebbles of underlying rocks, and constituting in this vicinity the base of the Carboniferous System.	

Devonian System.

1. *Mispeck Group.*—Dark-red and greenish shales; flaggy sandstones and grits; coarse angular conglomerate . .	1850
2. *Little River Group* (Upper part and passage beds).—Reddish conglomerate, with quartz pebbles; reddish, purple, and gray sandstones and grits; deep-red, gray, and pale-green shales. A few fossil plants	2350
3. *Little River Group* (Middle and Lower part).—Blackish and	

* Journal of Geological Society, Nov. 1862. † *Ibid.*, 1865.

gray hard shale and arenaceous shale (*Cordaite* shales in part); buff and gray sandstone (*Dadoxylon* sandstone) and flags. Many fossil plants; Crustaceans and *Spirorbis* .	Feet. 2800
4. *Bloomsbury Group.*—Reddish conglomerate, with slaty paste and rounded pebbles; trappean or tufaceous rocks; red, purplish, and green sandstones and shales. Thickness variable	2500
Lower Silurian System.	
5. Black papyraceous shale, with layers of cone-in-cone concretions	400
6. Hard, generally coarse and micaceous, gray shales and flags, of various shades of colour, and with some reddish shale and tufaceous or trappean matter at the bottom. *Lingulæ*, burrows, and trails of animals. Also in certain beds, *Paradoxides*, *Conocephalites*, and other primordial Trilobites	3000 feet or more

The following details as to the several members of the Devonian are abridged from Professor Bailey's and Mr Matthew's excellent memoirs already referred to. Before giving these, I may explain that the several members of the Devonian system form, on the east side of St John Harbour, a trough or synclinal form, and that from the eastern extremity of this some of the members of the series are believed to extend for a great distance to the eastward, in a more or less metamorphosed state. The general arrangement is shown in the section, Fig. 178.

Mispeck Group.

"The deposits of this group, constituting the newest member of the Upper Devonian series, occupy, in comparison with the groups to be described, a very limited area. So far as certainly known, they may be said to be confined within the narrow district intervening between the Little and Mispeck Rivers, and consequently occupying the centre of the trough already pointed out, as formed by the folding of the Upper Devonian groups.

"They rest immediately upon the beds of the Cordaite shales, and so nearly resemble the latter as to be not easily distinguished. It is therefore not unlikely that the group may yet be found to have a wider distribution, especially westward of the St John River, in the peninsula of Pisarinco.

The following descriptive remarks taken from the paper of Mr Matthew well represent its general character.

"West and north of Mount Prospect, where the Cordaite shales disappear beneath the stratified gravel which covers the top of that hill, the dip of the beds at the base of this group rapidly diminishes

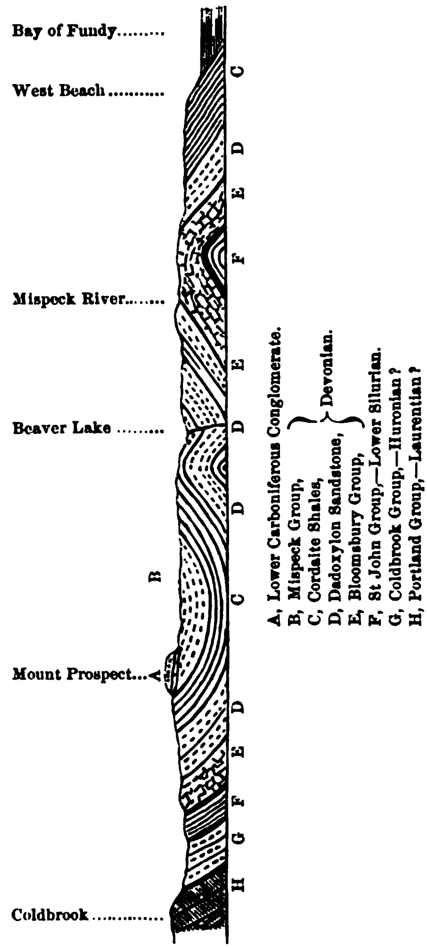


Fig. 178.—*Section from Coldbrook to West Beach, New Brunswick.*

from 30° to 15°, and the strike at the same horizon varies 10°. The lowest member is a coarse reddish conglomerate, having a red slaty paste filled with large subangular fragments of a gray altered rock, like the lower slate of the Coldbrook group. It also contains fragments of reddish sandstone, and a few pieces of impure slaty limestone. The conglomerate is overlaid by thick beds of purple clay

slate, which, by accession of coarser materials, becomes a slaty sandstone and grit filled with white particles. The strata of this group are much thicker on the north than on the south side of the basin. An isolated deposit of red slates, resembling the finer beds of this group, rests against a mass of altered rock, which seems to be a continuation of the Bloomsbury volcanic beds, at Taylor's Island, west of the Harbour of St John.

"If the beds last alluded to be properly referred, it is very probable that those of Pisarinco, already mentioned, may in part at least appertain to the same group. They have been described, however, as forming a portion of the Cordaite shales. The same is true in part of the district between Musquash and Chance Harbour."

Little River Group.

"The Little River group consists of two members, one of coarse and the other of comparatively fine ingredients, termed, from the characteristic fossils which they hold, the Dadoxylon sandstone and the Cordaite shales. Though intimately connected, they do not invariably occur together, and for this reason as well as others, will be separately considered."

"(A.) *Cordaite Shales.*—In the consideration of this, the upper member of the Little River group, we have presented for our study by far the most useful and interesting deposit which occurs in this portion of New Brunswick, if not indeed in the whole province. Recognising its economical importance as a rich metalliferous series, it has been one of the special objects of the present survey to ascertain minutely the distribution, age, and characters of the rocks composing it, and to mark its limits accurately as the great copper-bearing group of Lower New Brunswick. Although the greater portion of the country occupied by this series is still uncleared, and among the wildest and most rugged in the province, we have so far succeeded in tracing out its rock formations, that the limits of the latter may now be looked upon as approximately fixed, at the same time that its age and productive metalliferous character are satisfactorily established. As the details of this examination are of great importance, I shall here describe the observations made more minutely than in the case of the other groups has been deemed necessary.

"It will naturally be supposed that, forming as they do two members of a single group, the Dadoxylon sandstone and Cordaite shales should be intimately associated and occur together, and that the distribution of the former should be a general indication of the position of the latter. While, however, this is true as regards that portion of the

group occurring in the neighbourhood of St John, it has been ascertained that the Dadoxylon sandstones constitute a comparatively local deposit, while the shales which succeed spread much more widely over extensive districts, both to the east and west.

"On the eastern side of the Harbour of St John, the shales referred to are first met along the coast near the mouth of the Little River, where they form a narrow band lying between the embouchure of that stream and the promontory of Red Head. The band of rocks thus appearing, though narrow at the coast, widens as it is traced into the interior of the peninsula, and follows approximately the curve already pointed out as marking the distribution of the subjacent sandstone. The line of its outcrop may be readily traced on the geological map, forming a sharp and somewhat irregular curve, extending from Red Head to the mouth of the Mispeck. In the latter portion of the curve, owing principally to a fold in the strata, the rocks occupy a somewhat wider space than is covered in the former.

"Terminating on the coast at the locality last mentioned, the Cordaite shales, now trending south-westerly, seem for the moment to be lost in the waters of the bay. Like the sandstones which underlie them, however, they follow the curve of the volcanic beds of the Bloomsbury group, and doubling the promontory which marks the south-western termination of the latter, reappear along its eastern flank, still resting upon the Dadoxylon sandstone, and extend in this direction to the mouth of Emerson's Creek. Along this portion of their distribution, however, between the Mispeck and Black Rivers, there is a great difference in the character of the group observable, so great a difference, indeed, as to have caused some hesitation in assigning these beds to their true position. They occupy the coast from the point south-west of the Millicent Lake, including Beveridge and Thomson's Coves, as far as the mouth of the Black River. On the eastern side of the latter they extend along the shore to Emerson's Creek, and in the interior to a somewhat greater distance, but from this point are rapidly covered with the Carboniferous deposits which extend to Quaco. They reappear, however, north-west of the last named place, and eastward of Tynemouth or Ten-Mile Creek, where they rise into a low ridge, consisting chiefly of the conglomerates at the base of the series, and are crossed by all the principal roads leading in this direction.

"The same series has also been observed on Vaughan's and Macomber's Brooks, north-east of Quaco, covered as before by Carboniferous deposits on its southern slope, and to a less degree

on its northern also, where, however, it is succeeded, at a very short distance, by beds of the Lower Coldbrook. Owing to the disturbances and foldings alluded to in the description of the latter, the whole vast mass of the Lower and Upper Bloomsbury, St John slates, and Dadoxylon sandstones, have mostly disappeared, and we here find beds even below the base of the Silurian almost side by side with the shales of the Upper Devonian.

"From Vaughan's Brook, in the neighbourhood of Quaco, the upper member of the group now under consideration begins rapidly to widen, and to the eastward soon attains an enormous development. Higher members than those last described appear at Melvin's Beach; and thence, with the exception of a few isolated Carboniferous deposits at Salmon River, Goose Creek, and Martin's Head, extend with a bold and unbroken front along the coast to Point Wolf, at the western limit of Albert County. They thence no longer keep the shore, but, pursuing their normal course, may be traced in a series of bold high ridges as far as Shepody Mountain.

"While the southern limit of the group is thus uniform and regular, the line which marks its northern boundary is more difficult of recognition. Owing to one or more immense synclinal folds, the area covered by these rocks is enormously increased, and from the limited space occupied near the sea coast, behind Quaco, now widens until it embraces the whole extent of country south of the Shepody Road. On the latter thoroughfare the rocks of the group were first observed near Wallace's Post Office, in the parish of Hammond, King's, and near the source of the Great and Little Salmon Rivers. On the last named stream they were found to occupy the whole country southward to the coast. Whether they similarly occupy the entire valley of the former has not been ascertained: the difficulties of descending these rapid and mountainous water-courses, through a country without a settlement, being of too serious a character to admit of exploring both of the above named streams. The limits of the group in this direction, however, cannot vary far from the outlines as laid down on the Map.

"Following the line of the Shepody Road from the point above mentioned, the rocks of the present group, or 'coast series' as it may conveniently be termed, have been distinctly traced to the eastward as far as the high lands back of Hopewell, while deposits, probably referable to the same series, have been observed at a great variety of places both in the county of King's and eastward in that of Albert." These will be found severally referred to in the remarks on the characters of the group in Professor Bailey's Report.

"In general, it may be stated that the upper limit of the series is a line extending nearly northerly from the vicinity of Quaco, crossing the Shepody Road near the sources of the Salmon River, thence extending in the same line so as to include a large area in the parish of Hammond, to near the sources of the Pollet River. It follows the line of the Shepody Road eastward into Albert, and certainly includes all that portion of the latter county which lies southward of that road, between it and the sea; while the character of the metamorphic series which appear to the northward would seem to indicate even a wider distribution. Like all the older formations in this portion of the province, the Little River group is progressively covered to the eastward with Carboniferous deposits, which at Shepody Mountain finally cap the subjacent metamorphic beds, and form their well-marked eastern termination.

"Before the commencement of the present season's work, our knowledge of the extent of this most important group was limited to the area immediately about St John, and eastward to Black River and Gardner's Creek. We have now succeeded in fixing its true limits in this direction, and in giving to it a distribution which, to say the least, is as gratifying as it was unexpected.

"But not only have these metalliferous rocks been thus found to occupy such an extensive area to the east; they have also been found to spread widely to the west, and to give promise of valuable discoveries in a region to which, as yet, but little attention has been paid. I refer to portions of the peninsula of Pisarinco, west of St John, and to a large district south of the Musquash River, between the Lancaster Mills and Chance Harbour." Their distribution in this direction is discussed at length in the Report above referred to.

"(B.) *Dadoxylon Sandstone.*—The lower member of the Little River group, to which the preceding name has been applied, immediately succeeds and rests upon the upper member of the Bloomsbury. Folded with the latter into a depression or trough, it has been traced by Mr Matthew in a double curve extending from Manawagonish, west of the Harbour of St John, around, and along the southern flank of the Bloomsbury axis, maintaining throughout this district a nearly uniform width.

"On the eastern side of Courtnay Bay, it first appears near the mouth of Little River, and thence following the line of the Bloomsbury beds below it, extends northerly and easterly towards the head of the Mispeck, being very well exposed at Mount Prospect, about four miles east of the city. Near the sources of the Mispeck the band

of these rocks bends slowly around, assumes a southerly direction, and follows the last named stream to within a few miles of its mouth. Again changing its direction, it now flanks the end of the Bloomsbury ridge, and extends in a narrow belt eastwardly as far as the east branch of the Black River. Beyond the latter, as far as known, it rapidly disappears.

"To the west of St John, besides the locality of Manawagonish, the Dadoxylon sandstones have been observed on the west branch of the Musquash River, in the village of Ivanhoe, resting upon a deposit of the Upper Bloomsbury and overlaid by Cordaite shales.

"It will be remarked, when describing the characters of the Bloomsbury group, that the red deposits, which form its upper member, constitute beds of transition between that group and the one now under consideration.

"As indicated by the name it bears, the Dadoxylon sandstone is chiefly composed of coarse materials, though less so than in the group which immediately preceded it. While the upper beds of the latter consisted chiefly of reddish conglomerates, the present series is composed of a hard gray sandstone, associated, however, with occasional beds of grit and layers of dark gray shale. The transition above alluded to consists, therefore, in a gradually increasing fineness in the sedimentary beds, indicating changes in the physical conditions under which they were deposited.

"In lithological characters, the Dadoxylon sandstone, as described by Mr Matthew, is remarkably uniform and constant, and has been of great service in the study of the geology of the section now under consideration. But the chief interest which attaches to this deposit, is derived from the abundance and wonderful perfection of the organic relics which it holds, the oldest undoubted relics of a land vegetation in this long series of formations."

Bloomsbury Group.

The Bloomsbury group, like the Coldbrook, which it closely resembles, comprises two very different series of sediments, the lower and older being volcanic, while the upper and newer is of aqueous origin. These must be separately considered.

"(A.) *Sedimentary Beds.*—The deposits of the Upper Bloomsbury, of purely aqueous origin, are generally found in bands of varying width, lying parallel to, and immediately above the volcanic deposits of the lower member. They may thus be traced, following the different distribution of the latter, almost throughout its entire extent. The greatest development of this member is along the space between

the Black and Mispeck Rivers, and towards the foot of Loch Lomond. On the southern shore of the latter red sediments also occur, which have been doubtfully referred to the Coldbrook Group, but may possibly be a continuation of the beds last described. On the south-eastern side of the Bloomsbury axis, the upper member of the group again appears, but it is here a comparatively thin deposit, and occupies but a very limited area.

"Turning to the westward, this member is also but poorly represented, and at Courtnay Bay does not exceed a thickness of 150 feet. In St John and Carleton, as well as at Sheldon's Point, it is wanting altogether. On the west bank of the Musquash, however, in the village of Ivanhoe, reddish sediments occur resting upon the Portland series and overlaid by the Dadoxylon sandstone, and therefore belonging to the Upper Bloomsbury, but whether they have any direct connexion with the deposits to the east, or are the result of local and independent deposition, it is at present impossible to say.

"In lithological characters the upper member of the Bloomsbury group is very constant, consisting of fine-grained red clay slate and reddish-gray conglomerate. Its thickness has been stated at 500 feet. The rocks of this member, according to Mr Matthew, constitute a passage from the volcanic beds to the sandstone of the (Little River) group above. As far as known they contain no fossils."

"(B.) *Volcanic Beds.*—The most extensive and typical exposure of the volcanic beds of the present group is furnished by the locality from which their name has been derived, the high hill called Bloomsbury Mountain, near the centre of the parish of Simonds. This mountain, as described by Mr Matthew, constitutes the western termination of a ridge of land extending north-easterly in the centre of the county, and appears to represent one of the ancient fissures or volcanic vents, from which, during the Devonian period, were poured forth the lava, ashes, and scoria, which now constitute the lower member of the Bloomsbury group. The streams of eruptive matter thus discharged flowed from the central opening in three directions, north-easterly, westerly, and south-westerly, as indicated by the positions which they now occupy.

"The upper limit of the Bloomsbury lava streams, trending to the west, may be traced in a long, though narrow, line of hills, from the head of Black River, below Loch Lomond, to Courtnay Bay. Removed by denudation from the latter, the beds of the group reappear in the southern part of the city of St John, and again on the oppo-

site side of the harbour in the town of Carleton. They are somewhat increased in bulk in the latter place, but soon disappear to the westward under extensive accumulations of post-pliocene gravels. At Sheldon's Point, however, and Manawagonish, rocks probably referable to the present group occur, and beyond in the peninsula of Pisarinco, as well as on the Musquash River, and westward towards Lepreau.

"The second great belt of Bloomsbury lavas, trending southwesterly, though in much thicker beds than those last described, is comparatively limited in distribution, reaching only from the central vent of Bloomsbury Mountain to the Millicent Lake, in the rear of Mispeck. The valley of Black River cuts directly across, and is largely included in the series referred to, and in its upper part forms the line of division between its two members. The thickness of the lower member, as measured by Mr Matthew, has been approximately stated at 2000 feet.

"Of the eastward flow of the Bloomsbury lavas, little is known. Notwithstanding the great thickness of the group near the sources of Black River, it can be traced but a short distance in this direction, being rapidly covered and concealed by the Carboniferous deposits in the rear of Quaco.

"At Bloomsbury Mountain, where the best exposure has been stated to occur, the following peculiarities have been noticed by Mr Matthew:—

"'The elevation consists of basaltic trap, and is flanked on each side by beds of amygdaloid, trap-ash, and other products of volcanic origin, which also cover the crest of the anticlinal fold for two or three miles west of the hill. The succession of strata is best displayed on the south side of the hill, where they succeed each other in the following order:—Basaltic trap, unstratified, of great thickness; bedded basalt, amygdaloidal porphyry, bedded basalt, hornblendic trap-ash, micaceous quartzite, vesicular trap-ash slate; thickness of the stratified deposits about 3000 feet. There is also on this slope a volcanic conglomerate, viz., fragments of trap rocks imbedded in trap-ash slate. The quartzite resembles some of the finer beds at West Beach and Black River, and the porphyry is that alluded to in Gesner's Third Report, p. 15. The trap-ash slate is in many places full of irregular vesicles, the sides of which are coated with minute crystals of quartz, calcite, and specular iron.'

"The remaining portions of the lower Bloomsbury beds do not differ from those above described, except in the comparative infrequency of unstratified basalt."

The Devonian rocks appear at several places along the coast of New Brunswick, between St John and St Andrews, at which place they are connected with the Devonian sandstones of Perry, Maine. According to Professor Hind, an area of about twenty-five square miles near Campbellton on the Restigouche, consists of Devonian rocks, an extension or outlier of the Devonian of Gaspé. It is possible that some of the belts of Devonian rocks known to exist in the interior of Maine may extend into Northern New Brunswick; but this has not, I believe, been as yet certainly ascertained.

I must refer to Professor Bailey's Report for more full details on the Devonian of New Brunswick, and shall now turn to the more particular consideration of the highly fossiliferous members of the group as developed near St John, reserving for a subsequent chapter the consideration of the fossil plants.

Section at the "Fern Ledges," near St John.

Much interest attaches to that part of the St John section described above as the Little River group, on account of its fossil plants and insects; and for this reason I give below an abridgment of the detailed section prepared by Mr Hartt for Professor Bailey's Report, and which will serve to show the resemblance as to mineral character between these beds and those of the Coal formation. Mr Hartt remarks in introducing his section:—

"Of the several localities for fossil plants in the vicinity of St John, the richest and most interesting is that of the 'Fern Ledges.' These are a series of ledges exposed on the sea-shore, between high and low-water mark, at the foot of the properties of Messrs N. S. Demill and Zebedee Ring, Duck Cove, Lancaster, about a mile west of the town of Carleton. The ledges are formed by the outcropping edges of beds of sandstone and shale belonging to the Little River group of Mr Matthew. These have a strike of about W. 10° N., and a southerly or seaward dip of about 45°. This strike corresponds very nearly to the trend of the shore, along which, rounded and much worn by wave action and buried in sea-weed, their edges run in long ridges. The shale-beds, in which the plants occur, are, on account of their softness, everywhere so worn away by the waves from between the enclosing sandstones, as to be in only a few places accessible.

"Only near high-water mark are the ledges of any height, and from these the plant-bearing shale-beds are almost entirely removed. The ledges extend along the shore for some 325 paces, with a width of 300 feet, more or less, exposing a thickness of strata of about 150

feet. Numerous faults occur at the locality, the principal of which, on the easternmost side of the most prominent projecting ledge, and whose direction is S. 30° W., is a downthrow of about 50 feet.

"Directly in front of the ledges, and about half a mile from the shore, is a series of skerries laid bare at low water, called the 'Shag Rocks.' I have not visited them, but the beds of which they are composed have an apparent east-and-west strike, and a high dip to the southward. They are probably the upper members of the Cordaite Shales.

"Beds of sandstone and shale, similar to those at the Fern Ledges, show themselves on the shore about three-quarters of a mile to the westward. They contain the remains of a few species of plants identical with those occurring at the 'Ledges,' but the beds are higher up in the series. This locality, called the 'Calamite Ledges,' has not been so carefully examined as that to the eastward. I have collected there the following species, nearly all of which are common to the two localities:—

"*Cordaites Robbii*, Daws. Extremely abundant in certain layers of black shale, and very finely preserved. — *Sphenopteris Hitchcockiana*, Daws. Abundant in detached pinnules. — *Pecopteris discrepans*, Daws. Apparently rare: have found but a single pinnule. —*Cardiocarpum cornutum*, Daws. Not infrequent, associated with cordaites, calamites, etc.—*Calamites transitionis*, Goeppert. Abundant. — *C. cannæformis*, Brongn. — *Annularia acuminata*, Daws. *Pinnularia dispalans*, Daws. Common. — *Psilophyton? glabrum*, Daws. — *Stigmaria ficoides* (*var.*), Brongn. — A single specimen with rootlets attached was found by my father, J. W. Hartt, in a bed of sandstone, about half-way up in the section here exposed. —*Lepidodendron Gaspianum?* Daws. Two or three ill-preserved specimens of a Lepidodendron, which Dawson has referred with doubt to this species, were collected at this locality by Mr Matthew and myself.

"The sandstone at the Fern Ledges is very compact and hard, and of a gray colour. It contains many plant remains, but usually in a badly preserved state. Thin beds of arenaceous shale, of a fine texture and dark-gray colour, becoming black sometimes, or passing into light greenish-gray, are interstratified with the sandstones, and these beds are highly charged with plants, which occur preserved as graphite, every nerve and nervule of a fern leaf being as distinct as in a pencil drawing.

"It had been ascertained several years ago by Gesner, Robb, Dawson, and others, that the beds of the Little River group were

fossiliferous, and ill-preserved plant remains had been observed in the sandstones of the 'Ledges.' Mr Matthew, who had previously discovered in the shales at the foot of the city of St John, near the barracks, the plants which Dawson described in his paper on the 'Flora of the Precarboniferous, etc.,' collected in 1860, at the 'Ledges,' from one of the exposures of Plant-bed No. 1, of the following section, some obscure markings which were probably leaves of *Asterophyllites longifolia*, Brongn.; but it was not until May 1861 that I found that these rocks were richly fossiliferous, and discovered in Beds Nos. 1, 2, 3, and 8 (?), a large number of fossil plants, principally ferns, a remarkable Crustacean, *Amphipeltis paradoxus*, Salter, and a *Spirorbis*. Messrs Matthew, W. R. Payne, James Hegan, and Lunn, took part in the explorations which were carried on during the summer, Mr Matthew discovering, among other things, a new species of *Eurypterus*, *E. pulicaris*, Salter; while Mr Payne secured a single specimen of a trilobite, still undetermined, the only one the locality has afforded.

"These discoveries proved so interesting that Principal Dawson, to whom I communicated them, paid a visit to St John, and examined the locality in person. The collections made were put into his hands, and the plants were described in detail in his paper published in the Quarterly Journal of the Geological Society, entitled, 'On the Flora of the Devonian Period in North-Eastern America.' The number of plants obtained thus far from the Lancaster localities was 36, which, with the three species of Crustacea, the *Spirorbis*, and the three species of plants previously collected in St John by Mr Matthew, made the number of species of animals and plants ascertained to occur in the Little River group, 43.

"The following summer I spent thirty days at this locality, being rewarded by the discovery of some ten or more new species of plants, principally ferns, and by securing larger and more perfect specimens of many of the species described by Dawson from mere fragments. But the most valuable and entirely unexpected discovery, was that of *remains of insects*, of which five species have been obtained. These specimens are in the hands of my friend Mr Scudder of Boston, the well-known entomologist, for description. During the summer, I began the task of examining every bed in the section at this locality, a task not easy to perform, where the tough rocks lying below high-water mark and buried in a luxuriant growth of sea-weed, are worn away in such a manner as to make it difficult to work them.

"In the summer of 1863, I spent eight days at the locality, during which time I finished my section. Several new plants were discovered,

together with many quite perfect specimens of several hitherto known only as fragments. Of the latter was a large frond of *Neuropteris polymorpha*, Dawson.

"In the following section, the measurements were taken along a line crossing the beds at right angles to their strike, from high-water mark near the bathing-house stairs, to low-water mark. The rich fossiliferous shale-beds, or *plant-beds*, as I shall term them, are numbered from below upwards, for convenience of reference. The thickness and lithological character of these beds vary somewhat in their different exposures. The position of one or two plant-beds appearing elsewhere at this locality, but not observed on the line of section, is indicated. I have given lists of all the plants, etc., described, which I have collected from each plant-bed, with some remarks on their mode of occurrence, and I have noticed some of the undescribed species.

"The following section begins at the base of the Dadoxylon sandstone beds, at their junction with the trappean beds of the Bloomsbury group, which form the high land skirting the shore to the northward, and takes up the overlying beds in ascending order:—

"*Section of the Little River Group at the 'Fern Ledges,' Lancaster, N.B.* By Mr C. F. Hartt.

Heavy beds of gray sandstone and flags (Dadoxylon sandstone). *Dadoxylon Ouangondianum*, Daws., *Calamites, etc.*

Thickness, by estimation, 300 feet.

Under this head I have classed all the beds underlying the Plant-bed No. 1, which I am disposed to regard as the lowest of the rich plant-bearing layers, and the base of the Cordaite shales. These beds occupy the low ground lying between the ridge of the Bloomsbury group and the shore. They are covered by drift, and show themselves only in limited outcrops, and in the ledges on the shore. In the western part of the ledges they are thrown forward on the beach by a fault, forming a prominent mass of rock, in the summit of which a fine trunk of *Dadoxylon* is seen embedded in the sandstone. Recent excavations made in these beds in quarrying stone for building purposes, in the eastern part of the locality, where the rocks are very much broken up by dislocations, have exposed numerous badly preserved impressions of large trunks of this tree.

PLANT-BED No. 1 . . . . . . Thickness, 1 foot.

Black arenaceous shale, varying from a fissile sandstone to a semi-papyraceous shale, very fine-grained and very fissile, charged most

richly with beautifully preserved remains of plants, among which are the following species:—

Calamites transitionis, Goeppert. Occasional, in large, *erect* specimens.—*Asterophyllites latifolia*, Daws. Extremely abundant, often showing ten or twelve whorls of leaves, sometimes with many branches.—*A. acicularis*, Daws. Also very abundant.—(?) *A. longifolia*, Brongn.—*A. scutigera*, Daws. The curious stems of this species, with their scale-armed nodes, occur abundantly in this bed.—*Sphenophyllum antiquum*, Daws.—*Pecopteris obscura*, Lesqx.—*Sphenopteris* sp.?—*Cardiocarpum cornutum*, Daws. Rare.—*Psilophyton elegans*, Daws. Occasional. I have never detected any trace of *Cordaites Robbii*, Daws., in this bed. It is extremely common in the everlying strata.

Gray sandstones and flags, with occasional ill-preserved plants, *Calamites transitionis*, Goeppt., *Cordaites Robbii*, Daws.—*Asterophyllites and Sternbergiæ*	2 feet 6 inches.
Black arenaceous shales of the same character as those of No. 1, but without fossils, so far as I have examined	11 inches.
Compact flaggy, gray sandstone, with badly preserved plant remains, *Calamites*, etc.	2 feet.
Very soft, dark, lead-coloured shales, much slicken-sided and charged with fragments of plants. This bed is so soft that the action of the weather and the sea have everywhere denuded it to the level of the beach . .	4 feet.
PLANT-BED No. 2	1 foot.

At the point where the section crosses the bed, and where I first discovered it, it consists of very compact and hard, light lead-coloured, slate-like, arenaceous shale; but the character of the shale varies much in its different exposures, being sometimes very soft and fissile, and of a very black colour. The following is the list of species which it affords:—

Calamites transitionis, Goeppt. Occasionally; never in good specimens.—*C. cannæformis*, Brongn. Occasionally; never in good specimens.—*Asterophyllites acicularis*, Daws. Rather rare.—*A. latifolia*, Daws. Rather rare.—*A. longifolia*, Brongn. Rather rare.—*A. parvula*, Daws. Whorls of a minute *Asterophyllites*, which may belong to this species, are not infrequent in this bed.—*Annularia acuminata*, Daws.—*Pinnularia dispalans*, Daws. Abundant.—*Psilophyton elegans*, Daws. Quite common, always in fragments, never in good specimens.—*P. glabrum*, Daws. Flattened stems, with a wavy

woody axis traced in a brighter line of graphite, occur in this bed, but always in fragments.—*Cordaites Robbii*, Daws. Extremely abundant, and very fine specimens may be obtained, especially from the upper part of the bed, and rarely specimens showing the base or the apex of the leaf.—*Cyclopteris obtusa*, Lesqx. Occurs very abundantly in detached pinnules.—*Cyclop. varia*, Daws. Rare.—*N. polymorpha*, Daws. Extremely abundant, never in large fronds.—*Sphenopteris Hœninghausii*, Brongn. Quite abundant, often in fine fronds.—*S. marginata*, Daws. Abundant, in fine fronds.—*S. Harttii*, Daws. Very rare.—The original specimen came from this bed.—*S. Hitchcockiana*, Daws.—*Hymenophyllites Gersdorffii*, Goeppt. Rather rare.—*H. obtusilobus*, Goeppt. Rare.—*H. curtilobus*, Daws.—*Pecopteris* (*Alethopteris*) *discrepans*, Daws. Amongst all the abundance of plants afforded by Bed No. 2, I have detected only one or two pinnules of this fern, which appears first in abundance in Bed No. 3. It is afterwards one of the most common species.—*Pecopteris ingens*, Daws. Very rare, only two or three fragments of pinnules having been found.—*Trichomanites* (?)—only a single specimen, probably, as Dawson has suggested, only the skeleton of a fern.—*Cardiocarpum cornutum*, Daws. Abundant, and very finely preserved, never attached.—*C. obliquum*, Daws. Quite abundant, also never attached.—*Trigonocarpum racemosum*, Daws. Rare.—*Eurypterus pulicaris*, Salter. The occurrence in Bed No 2 of this minute Crustacean was first detected by my friend Mr George Matthew. It is very rare, not more than four or five specimens having been found by Messrs Matthew, Payne, and myself, at the time of the description of the species by Salter. I have since that time succeeded in collecting nearly twice as many more, some of which appear to belong to a new species.—*Amphipeltis paradoxus*, Salter. The specimen figured in Salter's paper was found by Professor Dawson and myself, in breaking a piece of shale in my cabinet, that came from this bed. Only one other specimen has since been obtained. It consists of two or more of the thoracid segments, and was collected by Mr Lunn. It is in the collection of the Natural History Society of New Brunswick. In addition to the above species, this bed has afforded the following:—*Cyclopteris*, sp. nov —*Neuropteris*, sp. nov. A single specimen collected by Mr Lunn.—*Sphenopteris*, sp. nov.—*Spirorbis*, sp. (?) The leaves of *Cordaites* in the upper part of the bed are as

thickly covered with a little *Spirorbis* as are the fronds of the recent fucoids of the Ledges. The specimens are too poorly preserved for identification.—*Trilobites.* Mr Payne collected a minute trilobite from this bed. The specimen was sent by Professor Dawson to Mr Salter, but that gentleman has made no mention of it in his paper.—*Insect Remains!* In the summer of 1862, I discovered an organism in Bed No 2, which at the time I could make nothing of; but which I have since proved to be the wing of an insect. Several weeks after, I found in Bed No. 8 an unequivocal insect's wing. This discovery was followed by that of others, my father, J. W. Hartt, finding another in this bed.

Compact flaggy sandstone, quite barren . . 5 feet 10 inches.

PLANT-BED No. 3 . . . . . 10 „

Black and lead-coloured shales, quite compact in upper part, but in lower very crumbling, splitting irregularly, slicken-sided, often with polished surfaces, and traversed by thin quartz-veins. These shales are so soft that the sea and weather have everywhere denuded them to the level of the beach. There are now no exposures of the bed workable. The following are the fossils which occur in it:—

Calamites transitionis, Goeppt. Occasionally.—*C. cannæformis*, Brongn.—*Asterophyllites latifolia*, Daws. Very beautiful whorls of this plant are very common here, the whorls, though usually detached, being sometimes found united three or four together. *Annularia acuminata*, Daws. Common.—*Pinnularia dispalans*, Daws. Common.—*Psilophyton elegans*, Daws. Occasionally.—*P.* (?) *glabrum*, Daws. Occasionally.—*Cordaites Robbii*, Daws. Extremely abundant, but not so well preserved as in Bed No. 2. Leaves apt to be preserved as polished bands of graphite, with venation obliterated.—*Cyclopteris obtusa*, Lesqx. Not very abundant.—*Neuropteris polymorpha*, Daws. In beautiful specimens, common.—*Sphenopteris marginata*, Daws. Not common.—*S. Hœninghausii*, Brongn. Not common.—*Pecopteris* (*Alethopteris*) *discrepans*, Daws. It was here that I first discovered this species. It occurs quite abundantly, but always in fragments.—*Cardiocarpum cornutum*, Daws. Quite common.—*C. obliquum*, Daws. Quite common.

Coarse sandstone, full of obscure casts of *Sternbergiæ* and *Calamites* . . . . . . 6 feet 6 inches.
Soft shale and fissile sandstone, with *Calamites* . 0 „ 3½ „

Sandstones	2 feet	3 inches.
Shale, with obscure remains of plants . .	0 „	2½ „
Sandstones, barren, so far as examined . .	4 „	10 „
Sandstone and shale, with a few *Calamites* and *Cordaites*	0 „	9 „
Sandstone and coarse shale, with obscure markings	5 „	10 „
Light greenish, coarse shale, with fern-stems, *Cordaites*, and obscure markings, *Carpolites* (?)	0 „	7 „
Sandstones and coarse shales, with badly preserved vegetable remains	18 „	9 „

PLANT-BED No. 4 . . . . 1 „ 0 „

Coarse shales, affording at the point where the line of section crosses it—

Cordaites Robbii, Daws.—*Calamites transitionis*, Goeppt.—*Neuropteris polymorpha*, Daws.—*Psilophyton glabrum*, Daws.—*Pinnularia dispalans*, Daws.

I have examined at two different points, in the eastern part of this locality, a bed which appears to correspond to this. It is characterized there by a very beautiful *Neuropteris* (*N. Dawsoni*, Hartt) with long linear lanceolate pinnules decurrent on the rachis, to which they form a broad wing. The pinnules are often four inches in length. This is one of the most beautiful ferns occurring at the locality. Several other new forms are associated with it. Among these is a magnificent *Cardiocarpum*, nearly two inches in diameter (*C. Baileyi*, Daw.).

Sandstone with obscure markings . . . 9 feet 6 inches.

PLANT-BED No. 5 . . . . 6 „

Soft, fine-grained light-greenish shale.

Cordaites Robbii, Daws. Extremely abundant.—*Calamites canæformis*, Brongn. Found occasionally.—*Psilophyton* (?) *glabrum*, Daws.—(?) *Asterophyllites acicularis*, Daws.—*Pecopteris* (*Alethopteris*) *discrepans*, Daws. Quite abundant.—*Sphenopteris marginata*, Daws. Quite abundant.—*Sphenopteris marginata*.—*Pecopteris*, sp. nov. (?)—*Hymenophyllites*, sp. (?)—*Neuropteris polymorpha*, Daws. Very abundant.—*Spirorbis* occurs in the bed, attached to the leaves of *Cordaites*. I have never detected it in any of the beds higher up.

Compact flaggy sandstones and coarse shales, with a few plants, ... 8 feet.

PLANT-BED No. 6 . . . . 2 feet.

Fine-grained and light-coloured shale, with great abundance of *Cordaites Robbii*, and *Calamites transitionis;* above that a layer of coarse shale, with *Cordaites*, and stems of plants badly preserved, then a layer of soft, very friable shale, with few fossils; and, lastly, a layer of coarse shale of a greenish-gray colour, with—

Pecopteris discrepans, Daws. Abundant.—*Cordaites Robbii*, Daws. Abundant.—*Calamites cannæformis*, Brongn. *Neuropteris polymorpha*, Daws.—*Cardiocarpum cornutum*, Daws.—*Cardiocarpum obliquum*, Daws.—*Pecopteris*, sp. nov. Occurs abundantly in some of the overlying beds.

Sandstones and coarse shales, with abundance of plant-remains, principally *Cordaites* and *Calamites* . . . . . 5 feet.

PLANT-BED No. 7 . . . . 2 „

This is one of the richest plant-beds of the section. The shales composing it vary much in character in different exposures. They are for the most part of a gray colour, and compact, like a fine-grained sandstone, though they pass into a light-brownish, very fissile, soft shale, and there are some layers of a very black colour.

Cordaites Robbii, Daws. Very abundant, and in a beautiful state of preservation.—*Calamites transitionis*, Goeppt. Not abundant as good specimens.—*C. cannæformis*, Brongn. Rare.—(?) *Asterophyllites acicularis*, Daws. In very beautiful specimens, very common in certain thin layers. There are two or three other species, occurring also in the overlying beds, which appear to be new.—*Annularia acuminata*, Daws. Extremely plentiful.—*Pinnularia dispalans*, Daws. Extremely plentiful.—(?) *Psilophyton elegans*, Daws. I have obtained several specimens of a *Psilophyton*, growing in tufts, and closely resembling this species.—*Neuropteris polymorpha*, Daws. Occasional.—*Pecopteris* (*Alethopteris*) *discrepans*, Daws. Abundant, and obtainable in good specimens.—*Cyclopteris obtusa*, Lesqx. Occasional.—*Sphenopteris marginata*, Daws.—*Hymenophyllites subfurcatus*, Daws.—*Cardiocarpum cornutum*, Daws. Quite abundant.—*C. obliquum*, Daws. Quite abundant.—*C. Crampii*, Hartt.—*Alethopteris Perleyi*, Hartt.—*Sphenopteris pilosa*, Daws. Several other plants not yet determined.—*Insects*. A single insect's wing was obtained from this bed by my father and myself.

Compact sandstone and coarse shales (barren of fossils) . 3 feet.

PLANT-BED No. 8 . . . . 1 foot 10 inches.

Fine-grained, tough, but fissile sandstones, rather coarse shales, often of a greenish cast, and at the top a thin layer of very black shale very rich in plants. The middle portion does not contain so many plant remains, but the lower is as well stocked as the leaves of a herbarium. The following are the fossils I have collected from it:—

Cordaites Robbii, Daws. As usual in great profusion, and in very fine specimens.—*C. transitionis*, Goeppt. Occasional.—*C. cannæformis*, Brongn.—(?) *Asterophyllites acicularis*, Daws. Quite common, together with one or two other species apparently new, which occur also in Bed 7.—*Annularia acuminata*, Daws. Extremely common, especially in certain layers.—*Pinnularia dispalans*, Daws. Abundant.—(?) *Lycopodites Matthewi*, Daws. Rare.—*Cyclopteris obtusa*, Lesqx.—*Cyclopteris*, sp. nov.—*Neuropteris polymorpha*, Daws. Quite frequent in detached pinnules.—*Hymenophyllites subfurcatus*, Daws. Very common.—*Pecopteris* (*Alethop.*) *discrepans*, Daws. This is the most abundant fern in this bed. It occurs usually in detached pinnules, though not unfrequently in considerable fronds.—*Pecopteris* (*Alethop.*). Besides the above, there are three or four other species, some of which occur also in Beds 6 and 7.—*Cardiocarpum cornutum*, Daws. Not very common.—*C. obliquum*, Daws. Also not very common.—*C. Crampii*, Hartt. Quite common.—Several other species of plants not yet determined.—*Insects*. Two species, two specimens. One was obtained by my friend, Mr James Hegan.

Sandstones and coarse shales, with badly preserved *Cordaites Robbii*, Daws., *C. transitionis*, Goeppt., and *Pecopteris* (*A.*) *discrepans* . . . . 26 feet.
Fine-grained, light-greenish shale, with obscure remains . 1 foot.
Sandstone and shales, with *Calamites* and obscure markings . 23 feet.

This brings up the section to those beds which are exposed within a few feet of low-water mark. Owing to the short time during which the rocks are laid bare by the fall of the tide, to their hardness, and to the way in which they are rounded down by the surf, the work of exploring this part of the section is very difficult, and I have not been able to give them a very close examination. A very rich plant-bed crops out within a short distance of low-water mark on the very eastern margin of the Ledges. Its place in the section is somewhere near Bed 8. It is characterized by *Cyclopteris valida*, Daws., which

appears to be limited to it. The unique specimen figured in Dawson's Paper 'On the Flora of the Devonian Period, etc.' (plate xvii. fig. 52), came from this bed. I obtained here a magnificent frond of *Neuropteris polymorpha*, Daws., showing its structure finely, and the different forms of the pinnules in different situations on the frond. Many of the species common in the underlying beds are also to be found in this; but I am unable to give a complete list.

Total thickness of the beds embraced in this section . 444 ft. 11 in."

Fauna of the Devonian Plant-beds of St John.

It will be necessary to devote a separate chapter to the interesting plant-remains of St John, which present to us a picture of the vegetation of the world at a period anterior to that of the great coal-deposits, more perfect, perhaps, than that to be obtained in any other known locality. I shall notice here some small crustaceans and worms which lived in the waters into which these plants were drifted and four species of *Insects*, the very oldest known to geologists, and which flitted through the old Devonian woods.

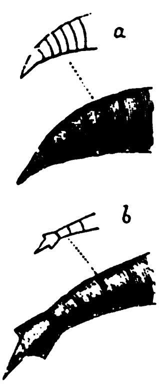


Fig. 179 (*a*, *b*).—*Eurypterus pulicaris.*

Fig. 180.—*Amphipeltis paradoxus.*

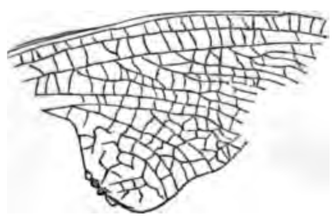
Attached to some of the fossil plants in the Cordaite shales, we have, just as in the Coal formation, shells of *Spirorbis.* I have not been able to satisfy myself as to whether these are the familiar *S. carbonarius* of the coal or a distinct species. The crustaceans found with them are of two species, one, a little shrimp-like creature, belongs to the genus *Eurypterus.* It was found by Mr Matthews, and has been described by Mr Salter as *E. pulicaris* (Fig. 179). The other is of higher type, perhaps allied to the modern Stomapods, and has been named by Mr Salter, to whom I sent the specimen,

which was from Mr Hartt's collection, *Amphipeltis paradoxus** (Fig. 180).

The insects found in these beds are of the very greatest geological interest, as being the oldest known representatives of that type. They occur in the same shales with the plants, and are thus proved, both by stratigraphical and palæontological evidence, to be older than the Carboniferous period. I have, therefore, figured the remains found, which are all from the collection of Mr Hartt, and which have been kindly described by Mr Scudder of Boston, one of our best authorities on questions of this kind. They were all Neuropterous insects, and allied to the Ephemeras. It is interesting, however, to observe that, like many other ancient animals, they show a remarkable union of characters now found in distinct orders of insects, or constitute *synthetic* types, as they have been named. Nothing of this kind is more curious than the apparent existence of a stridulating or musical apparatus like that of the cricket, in an insect otherwise allied to the Neuroptera. This structure also, if rightly interpreted by Mr Scudder, introduces us to the sounds of the Devonian woods, bringing before our imagination the trill and hum of insect life that enlivened the solitudes of these strange old forests.

Mr Scudder has kindly furnished descriptions of these insects as follows:—

Fig. 181.—*Platephemera antiqua*, Scudder.



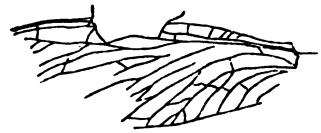
"The direction of the principal nervures in this insect convinces me that it belongs to the *Ephemerina*, though I have never seen in living *Ephemerina* so much reticulation in the anal area as exists here—so, too, the mode in which the intercalary nervules arise is somewhat peculiar. It is a gigantic species, for it must have measured five inches in expanse of wings—the fragment is a portion of an upper wing."

"At first sight the neuration of the wings seems to agree sufficiently with the *Sialina* to warrant our placing it in that family

* Journal of Geological Society, February 1863.

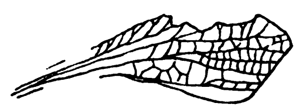
but it is very interesting to find, in addition to minor peculiarities, that near the base of the wing, between the two middle veins, there is a heavy cross-vein from which new prominent veins take their

Fig. 182.—*Homothetus fossilis*, Scudder.



rise; this is characteristic of the *Odonata*, and of that family only. We have, therefore, a new family representing a synthetic type which combines the features of structure now found in the *Odonata* and *Sialina*, very distant members of the *Neuroptera*. The fragment is sufficiently preserved to show the direction, extent, and mode of branching of nearly every principal nervure. It is evidently a portion of an upper wing; the insect measured not far from 3½ inches in expanse of wings."

Fig. 183.—*Lithentomum Harttii*, Scudder.



"This was the first specimen discovered by Mr C. F. Hartt, and I have, therefore, named it after him:—apparently, it does not belong to any family of Neuroptera represented among living forms. It agrees more closely with the family *Hemeristina*, which I founded upon a fossil insect discovered in Illinois, than it does with any other; but is quite distinct from that, both in the mode of division of the nervures and in the peculiar cross-veining. The fragment which Mr Hartt discovered is very imperfect; but, fortunately, preserves the most important parts of the wing. I am inclined to think that it was a lower wing. The insect probably measured 3½ inches in expanse of wing."

Fig. 184.—*Xenoneura antiquorum*, Scudder.

"Although in this fragment we see only the basal half or third of a wing, the peculiar mode of venation shows that the insect cannot belong to any known family of *Neuroptera*, living or fossil; yet it is evidently a Neuropterous insect. In addition to its other peculiarities,

there is one of striking importance, viz. :—the development of veinlets at the base of the wing, forming portions of concentric rings. I have endeavoured in vain to explain these away as something foreign to the wings, accidentally introduced upon the stone, and I know of nothing to which it can be compared but to the stridulating organ of some male *Orthoptera!* It is difficult to tell whether the fragment belongs to an upper or an under wing. Its expanse of wings was probably from 2 to 2½ inches."

Useful Minerals of the Devonian.

In Nova Scotia the only important mineral deposit known to be contained in the rocks of this system is the iron ore of Nictaux and Moose River. This is a conformable bed, at Nictaux about six feet in thickness, and quite accessible, as it crops out at the surface without any cover. The outcrop of the bed appears at several places in Nictaux, and also at Moose River, where the thickness appears to be less than at the former place. At Nictaux the ore is a peroxide of iron, laminated in structure, and full of fossil shells. At Moose River it is in the state of magnetic iron, but retains its characters in other respects. A specimen in my collection from Nictaux contains 55·3 per cent. of iron. This ore is thus of great value, but is not at present worked. Its distance from the coal-fields, and the consequent necessity of smelting with charcoal, are obstacles in the way of its commercial application.

In New Brunswick several important mineral deposits have been recognised in the Devonian of the south coast. The following account of them is from Bailey's Report. More full details as to one of these deposits, the Vernon Copper Mine, are contained in Professor Hind's Preliminary Report.

"*Iron Ores.*—The principal locality for this metal is the district in the vicinity of West Beach and Black River, where several large beds of hematite occur. As they are well known, and were described in a previous Report, it is not necessary to make further allusion to their character, than to say that one portion of the ore occurs in a coarse reddish-gray conglomerate, the other, two or three miles to the eastward, in beds of trappean and micaceous slates. These rocks have been shown by Mr Matthew clearly to form a portion of the Cordaite shales in the Devonian series.

"Besides the ore-beds alluded to, iron is abundant in seams and veins through most of the rocks occurring in this district, and it is not improbable that further search would reveal the latter in available quantities.

"The only remaining district likely to be productive of this metal is the peninsula of Pisarinco. I have already alluded to the resemblance between the latter and the beds of Beveridge Cove, and stated that specular iron is not uncommon in its southern portion. Were the metal in greater demand, its presence in this region might be looked for with very good prospect of success. The same is true of the district lying to the west of Musquash Harbour, and thence towards the Basin of Lepreau.

"*Copper Ores.*—The most important and well-known localities of copper, appertaining to this series, are the mines occurring in the eastern portion of St John, and western portion of Albert, counties. In the district alluded to, between Martin's Head and the settlement of Great Salmon River, no less than four distinct attempts have been made to carry on operations, with varying success. These constitute respectively the Vernon, Alma, Gordon, and Williams Mines. The three latter were visited by myself in the summer of 1863, and described in my Report of that year; the former, though also alluded to in the same Report, was not visited until the past season. It may therefore not be out of place to add a few observations, made by Mr Matthew and myself, upon its present condition.

"The Vernon Copper Mines are situated upon the Bay Shore, about three miles eastward of Martin's Head, and about two from the mouth of Goose Creek. The rocks in which operations have been begun are metamorphic beds of the Bay Shore belt, which here rise abruptly from the level of the sea to a height varying from six to eight hundred feet. Their character has already been described. They consist of dull purple and gray micaceous slates, conglomerates, and grits, much injected with igneous matter, and holding veins of quartz, calcspar and chlorite. They are in every way identical with the rocks of Martin's Head and the region to the westward, belonging, with the latter, to the Cordaite division of the Little River group, a formation referable to the Upper Devonian age.

"Since the date of my last Report, operations of a vigorous character have been begun, and a force of about forty men is now constantly employed. At the time of my visit, three adits had been driven near the base of the hill, and preparations were in progress for systematic labour. Owing, however, to the abrupt character of the shore, the want of a suitable harbour, and the difficulty of procuring supplies through the unsettled district above, active operations had been greatly retarded. A road is now being opened to connect the mines with the Shepody Road, and I believe it is the intention of the Company to erect a breakwater, whereby the obstacles at present existing may be greatly diminished.

"The rocks of the Alma, Williams, and Gordon Mines, are in every way similar to those of the Vernon, and, for this reason, do not require further notice. All mining operations at these localities have been for the present discontinued.

"In addition to the places above described, the following are localities appertaining to the Cordaite shales, in which the presence of ores of copper has been ascertained:—

"(*a.*) The shores of the Great Salmon River, Albert County, probably a continuation of the lodes at the Alma and Gordon Mines. *Ore*—Copper glance.

"(*b.*) On the Farm of Andrew M'Farlane, three miles back of Salmon River, Albert, and on the road to New Ireland. *Ore*—Peacock copper and yellow sulphuret, in dark slaty grits. No explorations have been made.

"(*c.*) Near entrance of Little Salmon River, St John County.* A small quantity of copper associated with much iron pyrites, occurring in slate.

"(*d.*) M'Lachland's Farm.* Indications somewhat more promising than at the last named locality.

"(*e.*) Near Martin's Head, at foot of the hills, on the north side of the marsh connecting the headland with the shore. *Ore*—Erubescite (or Peacock ore). The specimens seen were of a very rich character. No attempt had been made, at the time of our visit, to ascertain the extent of the deposit, but the locality is a promising one, and deserves further exploration. The facilities for the successful carrying on of mining operations are very superior to those of the Vernon Mine, the land being lower, and the shore protected by the promontory of Martin's Head. Indications of copper have also been observed upon the Head itself.

"(*f.*) Shepody Mountain. Near the Manganese Mine of Mr Steadman, a shaft has been sunk in greenish chloritic slate, to a depth of 50 feet in search of copper, which is said to occur in veins of quartz. The locality was examined by Mr Hartt, but no indications of that metal were observed. It has also been stated that *native* copper occurs in quartz veins in the conglomerates of the Manganese Mine.

"(*g.*) Black River Settlement, on the mountain road from Loch Lomond. *Ore*—Copper pyrites and the green carbonate, in hard clay slate.*

"(*h.*) Pisarinco. Yellow sulphuret of copper has been found in the altered slates and grits of this peninsula, but not in profitable quantities.

* Observed by Mr Matthew.

"At all the above named localities, the rocks are certainly members of the upper division of the Little River group. In those which follow, the beds are probably portions of the same series, but, as expressed in the remarks on the characters of this group, their position has not been ascertained with absolute certainty.

"(*i.*) Blackwood Block, Albert County. I am informed by Mr Matthew, that in this district, and near the lake which forms the source of one of the branches of the Salmon River, copper has recently been found by Mr G. F. Keans of St John.

"The latter gentleman observed some veins, and numerous boulders of quartz on the hillsides about the lake, as well as felspar, mica (silvery gray and black), hornblende, actinolite, and chlorite. The copper was observed in a ledge of hard gray metamorphic slate, on the north side of the lake, filling seams in the rock, and is a green carbonate, not the original ore. The accompanying rocks are described as paler and coarser slates, some of the latter having an ash-like aspect (volcanic ?), and reddish felsite. All of these rocks are similar to those occurring in the Cordaite shales, or cupriferous band of the coast. Both of the above named gentlemen, to whom I am indebted for the facts of its occurrence, regard the locality as a promising one, and deserving of further examination.

"This locality is not very distant from the point at which particles of drift gold were observed by myself and others in the summer of 1863. The occurrence of the latter is curious, and difficult of explanation. It can scarcely be supposed that this metal should have come from beds of Devonian age, such as those of the neighbourhood appear to be. Neither are there any rocks of a greater age in this portion of the province, unless we suppose the re-appearance of the St John slates, or some portion of the Coldbrook and Portland groups. As to the former, as far as observed to the eastward, no approaching alteration, such as is usually found in gold-bearing series, was observed, and eastward of King's County the group itself appears to be entirely wanting. The same is true of the Portland group, but it is not at all unlikely that beds of the Coldbrook may be represented in this district, and to them we must provisionally look for the origin of this metal. It should, however, be borne in mind, that Dr Hayes of Boston has, by analysis, ascertained the presence of gold in the rocks of the Vernon Mine, also a part of the series of which the locality at Blackwood is supposed to form a member.

"(*k.*) Beech Hill, Westmoreland. On the south-eastern side of the Memramcook River, in the parish of Dorchester, and about three miles from Charters' Inn, occurs a very singular metalliferous locality, but

recently discovered, and which opens a new field of investigation in a district heretofore supposed to be destitute of metal-bearing rocks.

"The precise locality where this discovery was made, is on the land of Joseph Landry, constituting a portion of the settlement known in the vicinity as Beech Hill. The land has been leased from its owners by Mr Alex. Wright of Salisbury, with whom I paid a visit to the spot during the past season.

"In examining the district where the ore occurs, I found that the land immediately surrounding the lode is everywhere covered with rocks of Carboniferous age, over the surface of which are scattered innumerable boulders of highly crystalline quartz. The beds from which the latter have been derived are not directly visible, but near the point where they are most abundant, a pit has been sunk to a depth of about five feet, exposing a distinct quartz lode of from four to five feet in thickness. This lode has a course about N. 22° W., a nearly perpendicular dip, and is bounded by regular walls. Only one of the latter was distinctly visible, and consisted of buff-coloured and reddish altered grit or breccia. Covering the latter, as well as a portion of the lode, are an ochreous clayey conglomerate, then a reddish slaty clay, and, finally, over all some two or three feet of soil. These uppermost deposits have a decidedly Carboniferous look, and are destitute of metallic indications.

"The ore, which is confined to the quartz lode, is the gray sulphuret, and is scattered through the rock in veins and spots, while, by alteration, it has given a green tinge to much of the associated gangue. A portion of the quartz is distinctly, and at times finely, amethystine (indicating the presence of manganese). Barytes is also found in the lode, and specimens from the neighbourhood contain a green variety of fluor. There seemed to be an entire absence of calcareous matter.

"Hoping that some exposures might be found in the neighbourhood, by which the age of the deposit could be ascertained, I made a careful search, but found no beds *in situ*, with the exception of Carboniferous sandstones, shales, and conglomerates, the former holding characteristic plants. Boulders, however, were common, and evidently derived from a metamorphic series, such as gneiss, syenite, mica schist, green and ashy slates.

"This locality is certainly an interesting one, and worthy of further exploration. It would seem to imply an easterly prolongation of the metalliferous coast belt, as well as a great thinning out of the Carboniferous beds by denudation. It is not unlikely that similar exposures, from which the boulders have been derived, may be discovered in the neighbourhood."

CHAPTER XXII.

THE DEVONIAN PERIOD—*Continued.*

FLORA OF THE DEVONIAN.

THE state of our knowledge of this subject at the time when the writer commenced his labours upon it, may be learned from the following extract from his paper of 1861, already referred to:—

"The known flora of the rocks older than the Carboniferous system has until recently been very scanty, and is still not very extensive. In Goeppert's recent memoir on the flora of the Silurian, Devonian, and Lower Carboniferous rocks,* he enumerates twenty species as Silurian, but these are all admitted to be Algæ, and several of them are remains claimed by the zoologists as zoophytes, or trails of worms and mollusks. In the Lower Devonian, he knows but six species, five of which are Algæ, and the remaining one a *Sigillaria*. In the Middle Devonian he gives but one species, a land plant of the genus *Sagenaria*. In the Upper Devonian the number rises to fifty-seven, of which all but seven are terrestrial plants, representing a large number of the genera occurring in the succeeding Carboniferous system.

"Goeppert does not include in his enumeration the plants from the Devonian of Gaspé, described by the author in 1859,† having seen only an abstract of the paper at the time of writing his memoir, nor does he appear to have any knowledge of the plants of this age described by Lesquereux in Rogers' Pennsylvania. These might have added ten or twelve species to his list, some of them probably from the Lower Devonian. It is further to be observed, that certain specimens found in the Upper Ludlow of England,‡ appear to prove the presence of *Lepidodendron* in that formation; and that, in the paper above referred to, I have noticed specimens from the Gaspé limestone which seem to me to indicate the occurrence of *Psilophyton* and *Noeggerathia* or *Cordaites* in the Upper Silurian of Canada.

* Jena, 1860.

† Journal of Geological Society of London, also Canadian Naturalist.

‡ Murchison's "Siluria," p. 152, Journal Geol. Soc. vol. iv.

"It thus appears that, according to our present knowledge, the plant life of the land, so rich in the Coal formation, dies away rapidly in the Devonian, and only a few fragments attest its existence in the Upper Silurian. Great interest thus attaches to these oldest remains of land plants; and fragmentary though they are, and often obscure, they merit careful attention on the part of the geologist and botanist.

"No locality hitherto explored appears more favourable to the study of this ancient vegetation than those parts of Eastern America to which this paper relates. The Gaspé sandstones have already afforded six Devonian species, some of them of great interest, and in a remarkably perfect state of preservation; and from beds of similar age in New Brunswick and Maine, I am now prepared to describe at least ten species, most of them new. This already raises the species found in the band of Devonian rocks, extending through the north-eastern States of the Union, and the eastern part of British America, to one-third of the number found in all other parts of the world; and the character of the containing rocks, the number of nondescript fragments, and the small amount of exploration hitherto made, justify the hope that a much larger number may yet be discovered."

In the paper from which the above extract is taken, the total number of American Devonian species was raised to twenty-one, of which seven were from St John. Subsequently the much larger collections obtained at this place, farther collections by the writer at Perry, and specimens kindly placed at his disposal by Professor Hall of Albany and Sir William Logan, have raised the known species to eighty-two; and have thus placed Eastern America, in the matter of pre-carboniferous land plants, in advance of Europe. To these I am now able to add eleven species recently obtained by Mr Hartt, and not before published, making the whole number ninety-three, of which fifty have been found in the St John beds.

The general character of the Devonian flora, in comparison with that of the Carboniferous period, may be thus stated:—

1. In its general character the Devonian flora resembles that of the Carboniferous period, in the prevalence of Gymnosperms and Cryptogams; and, with few exceptions, the generic types of the two periods are the same. Of thirty-two genera to which the species described in this paper belong, only six can be regarded as peculiar to the Devonian period. Some genera are, however, relatively much better represented in the Devonian than in the Carboniferous deposits, and several Carboniferous genera are wanting in the Devonian.

2. Some species which appear early in the Devonian period continue to its close without entering the Carboniferous; and the great majority

of the species, even of the Upper Devonian, do not reappear in the Carboniferous period; but a few species extend from the Upper Devonian into the Lower Carboniferous, and thus establish a real passage from the earlier to the latter flora. The connexion thus established between the Upper Devonian and the Lower Carboniferous is much less intimate than that which subsists between the latter and the true Coal measures. Another way of stating this is, that there is a constant gain in number of genera and species from the Lower to the Upper Devonian, but that at the close of the Devonian many species and some genera disappear. In the Lower Carboniferous the flora is again poor, though retaining some of the Devonian species; and it goes on increasing up to the period of the Middle Coal measures, and this by the addition of species quite distinct from those of the Devonian period.

3. A large part of the difference between the Devonian and Carboniferous floras is probably related to different geographical conditions. The wide swampy flats of the Coal period do not seem to have existed in the Devonian era. The land was probably less extensive and more of an upland character. On the other hand, moreover, it is to be observed that, when in the Middle Devonian we find beds similar to the underclays of the Coal measures, they are filled, not with *Stigmaria*, but with rhizomes of *Psilophyton;* and it is only in the Upper Devonian that we find such stations occupied, as in the Coal measures, by *Sigillaria* and *Calamites*.

4. Though the area to which this paper relates is probably equal to any other in the world in the richness of its Devonian flora, still it is apparent that the conditions were less favourable to the preservation of plants than those of the Coal period. The facts that so large a proportion of the plants occur in marine beds, and that so many stipes of ferns occur in deposits that have afforded no perfect fronds, show that our knowledge of the Devonian flora is relatively far less complete than our knowledge of that of the Coal formation.

5. The Devonian flora was not of lower grade than that of the Coal period. On the contrary, in the little that we know of it, we find more points of resemblance to the floras of the Mesozoic period, and of modern tropical and austral islands, than in that of the true Coal formation. We may infer from this, in connexion with the preceding general statement, that in the progress of discovery very large and interesting additions will be made to our knowledge of this flora, and that we may possibly also learn much more of the land fauna contemporaneous with it.

6. The *facies* of the Devonian flora in America is very similar to

that of the same period in Europe, yet the number of identical species does not seem to be so great as in the coal-fields of the two continents. This may be connected with the different geographical conditions in these two periods; but the facts are not yet sufficiently numerous to prove this.

7. The above general conclusions are not materially different from those arrived at by Goeppert, Unger, and Brongniart, from a consideration of the Devonian flora of Europe.

The following list includes all the species of the St John beds known up to the present time, the most important of which I shall endeavour to illustrate by short descriptions and figures:—

Dadoxylon Ouangondianum, *Dawson.*
Sigillaria palpebra, *Dn.*
Stigmaria ficoides (var.), *Brongn.*
Calamites transitionis, *Goeppert.*
—— cannæformis, *Brongn.*
Asterophyllites acicularis, *Dn.*
—— latifolia, *Dn.*
—— scutigera, *Dn.*
—— longifolia, *Brongn.*
—— parvula, *Dn.*
—— laxa, sp. nov.
Annularia acuminata, *Dn.*
Sphenophyllum antiquum, *Dn.*
Pinnularia dispalans, *Dn.*
Lepidodendron Gaspianum, *Dn.*
Lycopodites Matthewi, *Dn.*
Psilophyton elegans, *Dn.*
—— glabrum, *Dn.*
Cordaites Robbii, *Dn.*
—— angustifolia, *Dn.*
Cyclopteris Jacksoni, *Dn.*
—— obtusa, *Goeppert.*
—— varia, *Dn.*
—— valida, *Dn.*
—— Bockshiana, *Goeppert.*
Neuropteris Dawsoni, *Hartt.*
Neuropteris polymorpha, *Dn.*
—— sp. nov.
—— probably two other sp.
Sphenopteris Hœninghausi, *Brongn.*
—— marginata, *Dn.*
—— Harttii, *Dn.*
—— Hitchcockiana, *Dn.*
—— pilosa, sp. nov.
Hymenophyllites Gersdorffii, *Goeppert.*
—— obtusilobus, *Goeppert.*
—— curtilobus, *Dn.*
—— subfurcatus, sp. nov.
Pecopteris (Alethopteris) decurrens, *Dn.*
—— (——) ingens, *Dn.*
—— (——) obscura (?), *Lesquereux.*
—— preciosa, *Hartt.*
—— Perleyi, *Hartt.*
—— serrulata, *Hartt.*
Trichomanites, sp.
Cardiocarpum cornutum, *Dn.*
—— obliquum, *Dn.*
—— Crampii, *Hartt.*
—— Baileyi, sp. nov.
Trigonocarpum racemosum, *Dn.*
Antholithes Devonicus, sp. nov.

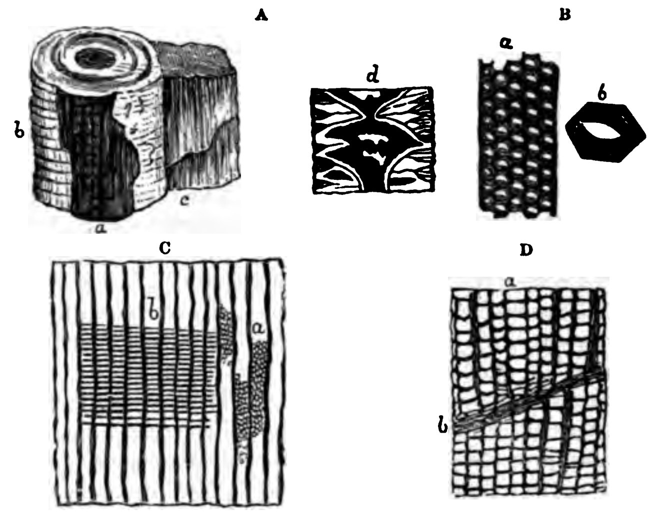
(*Coniferæ.*)

*Dadoxylon Ouangondianum.**—Dn. Trunks of this fine coniferous tree are frequent in the St John sandstones. They retain their structure in great perfection, especially in silicified specimens. Some of the trunks have been a foot or more in diameter. They show traces of growth-rings on their weathered ends, and when perfect, are traversed by the transversely wrinkled pith-cylinders, formerly known as *Sternbergiæ.* Under the microscope the wood-cells are seen to be of remarkable

* I have named this species after the ancient Indian designation of the St John River, *Ouangonda.* I use the generic term Dadoxylon as probably best known to English geologists; but I sympathize with Goeppert in his preference of the generic term *Araucarites* for such trees.

size, being fully one-third larger in their diameter than those of *Pinus strobus* or *Araucaria Cunninghami*, and also much larger than those of

Fig. 185.—*Dadoxylon Ouangondianum.*



A, Fragment showing Sternbergia pith and wood; (*a*) Medullary sheath; (*b*) Pith; (*c*) Wood; (*d*) Section of pith.
B, Wood cell (*a*), and Hexagonal areole and pore (*b*).
C, Longitudinal section of wood, showing (*a*) Areolation, and (*b*) Medullary rays.
D, Transverse section showing (*a*) Wood-cells, and (*b*) Limit of layer of growth.

the ordinary coniferous trees of the Coal measures. They are beautifully marked with contiguous hexagonal areoles, in which are inscribed oval slits or pores, placed diagonally. The medullary rays are large and frequent, but their cells, unlike the wood-cells (*prosenchyma*), are more small and delicate than those of the trees just mentioned. The pith when perfectly preserved presents a continuous cylinder of cellular tissue, wrinkled longitudinally without, and transversely within, and giving forth internally delicate transverse partitions, which coalesce toward the centre, leaving there a series of lenticular spaces, a peculiarity which I have not heretofore observed in these Sternbergia pith cylinders. It is interesting to find in a Devonian conifer the same structure of pith characteristic of some of its allies in the Coal formation, where, however, as I have elsewhere shown,* such structures occur in Sigillaria as well; and since Corda has ascertained a similar structure in *Lomatofloyos*, a plant allied to Ulodendron, it would appear that the Sternbergiæ may have belonged to plants of very dissimilar organization.

* Paper on Coal Structures. Journal of Geol. Soc.

In my specimen the pith is only half an inch in diameter, and only a small portion of the wood is attached to it; but Mr Matthew has a specimen of a trunk ten inches in diameter, with the pith one inch in thickness, and another 11½ inches in diameter, with the pith 2½ inches. Both had the appearance of decayed trunks, so that their original size may have been considerably greater.

Mr Matthew states in reference to the mode of occurrence of this interesting species, that the wood is always in the state of anthracite or graphite, or mineralized by iron pyrites, calc spar or silica. The pith is usually calcified, but in pyritized trunks it often appears as a sandstone cast with the external wrinkles of Sternbergia. The pith is often eccentric, and specimens occur with two or three centres; but these either consist of several trunks in juxtaposition, or are branching stems. The annual layers vary from one-eighth to one-thirtieth of an inch in thickness, and adjoining layers sometimes vary from one-tenth to one-twentieth of an inch.

The trunks of this species appear to have had a strong tendency to split in decay along the medullary rays, and in consequence the cross section often presents a radiating structure of alternating black lines representing the wedges of wood, and white rays of calc spar. The heart wood seems to have had its cell walls much thickened, and in consequence to have been more durable than that nearer the surface. They appear to have been drift trees, and to have been much worn and abraded before they were embedded in sediment.

(*Sigillariæ.*)

Sigillaria palpebra, Dn. Ribs narrow, about a quarter of an inch in width. Leaf-scars transversely acuminate, small. My only specimen is a small fragment, showing three or four ribs, and with only a few of the scars preserved. The most perfect leaf-scars are shaped much like a half-closed eye; but the specimen is only a cast, and very imperfect. Locality, St John.

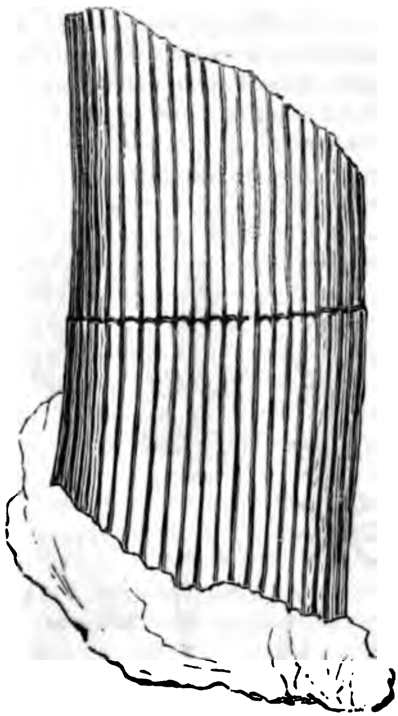
Stigmaria ficoides (variety), Brongniart. Large roots of *Stigmaria*, in some instances with rootlets attached, occur, though rarely, in the sandstone or arenaceous shale near St John—only two or three specimens having been found. They are not distinguishable from some varieties of the *Stigmaria ficoides* of the Coal measures.

(*Calamites.*)

Calamites transitionis, Goeppert. "Canad. Nat.," vol. vi. p. 168 (Fig. 186). This species, so characteristic, according to Goeppert, of the Upper Devonian and Lower Carboniferous series in Europe, is abun-

dant at St John, both in the sandstone containing coniferous trees, and the shales which afford Ferns, *Cordaites*, etc. Some of the beds of the latter are filled with flattened stems. This was one of the first fossils recognised in the St John rocks, specimens having been shown to me in 1857 by the late Professor Robb.*

Fig. 186.—*Calamites transitionis.*



Calamites cannæformis, Brongniart. This species, presenting the characters which it exhibits in the Coal measures, occurs in the ledges west of Carlton, associated with the last species, but in much less abundance. It is a widely distributed species, but has not, I believe, been found previously in rocks older than the Lower Carboniferous.

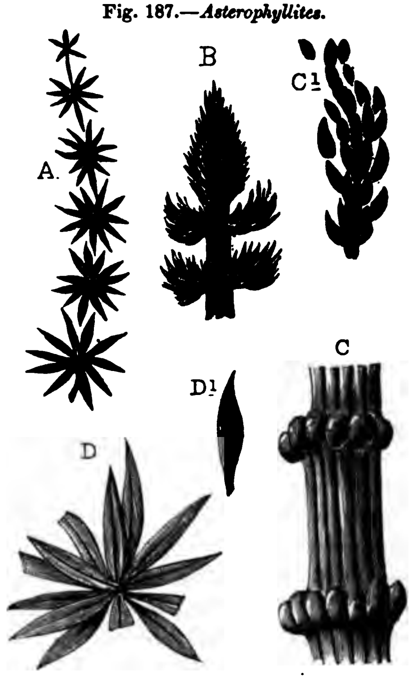
(*Asterophyllites, etc.*)

Asterophyllites acicularis, Dn. (Fig. 194, H and H[2]). Stems slender, striated, thickened at the nodes, leafy. Leaves one-nerved, linear,

* Dr Gesner mentions (Second Report, 1840, p. 12) a Calamite (probably this species) as occurring near Little River.

slightly arcuate, ten to fifteen in a whorl, longer than the internodes. Length of leaves one-half to three-fourths of an inch. This plant is abundant in some layers of shale near St John. It resembles *A. foliosa*, L. and H., but the leaves are longer, less curved, and more numerous in a whorl. Some of the specimens show that the stem was leafy, as well as the branches; and I have a specimen, apparently the termination of a main stem, showing the whorls of leaves diminishing in size toward the apex. My specimen of this and the following species of *Asterophyllites* are from the collections of Messrs Matthew and Hartt, and were obtained from the ledges and cliffs west of Carlton. I believe the small strobiles, one of which is seen at H² to be the fruit of this species.

Fig. 187.—*Asterophyllites.*



A, Asterophyllites latifolia. D, A. latifolia, larger whorl of leaves.
B, Do. apex of stem (?) fruit. D¹, Leaf.
C and C¹, Asterophyllites scutigera.

Asterophyllites latifolia, Dn. (Fig. 187, A, B, D). Stem somewhat slender, with enlarged nodes. Leaves oblong-lanceolate, about thirteen in a whorl, one-nerved, longer than the internodes. Length of leaves varying from one-fourth of an inch, near the ends of branches, to an

inch or more. This species abounds in the same locality with the preceding, and is often very perfectly preserved. It has some resemblance to *A. galioides*, L. and H., and to *A. fertilis*, Sternberg; but it differs from the former in the number and form of the leaves, and from the latter in the acuteness of their points. The fruit or growing extremity of the stem is represented at (B).

Asterophyllites (?) *scutigera*, Dn. (Fig. 187, C.) Stems simple, elongated, attaining a diameter of half an inch, obscurely striated; bearing on the nodes whorls of round or oval scales, or flattened nutlets, which at the ends of the stems are crowded into a sort of spike, while on other parts of the stems the nodes are sometimes an inch apart. This is a plant of uncertain nature, which I place only conjecturally in this genus. The stems, which are very long, may have been horizontal or immersed, and the apparent scales may either have constituted a sort of sheath, as in *A. coronata*, Unger, or may have been seeds or nutlets flattened like the rest of the plant. Near some of the specimens are fragments of linear leaves, which may have belonged to this plant, though I have not found them attached. When flattened obliquely, the stems appear as rows of circular marks, which represent the harder tissue of the nodes, and have a very singular appearance. This plant, though found with the preceding, does not occur in the layers which contain the other plants; and this may possibly mark a difference of habitat.

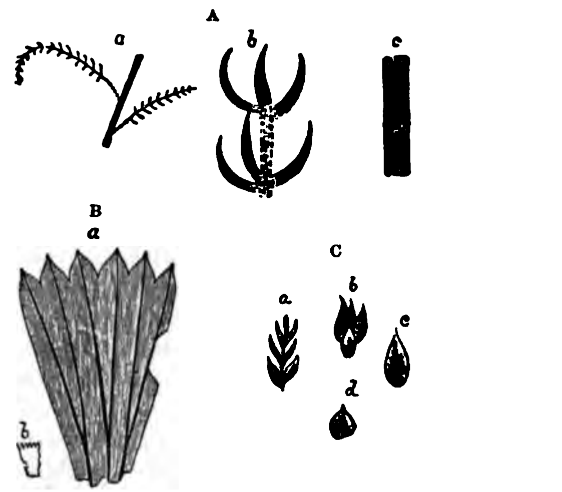
Asterophyllites longifolia, Brongniart. In the shales containing the preceding species are some fragments of an *Asterophyllites* with slender stems, internodes about an inch in length, and linear leaves two or three inches in length, and about six to eight in a whorl. It may belong to the species here named; but the remains are not sufficiently distinct to render this certain.

Asterophyllites parvula, Dn. (Fig. 188, A). "Canad. Nat.," vol. vi. p. 168, figs. 6 *a*, *b*, *c*. Branchlets slender. Leaves five or six in a whorl, subulate, curving upwards, half a line to a line long. Internodes equal to the length of the leaves or less. Stems ribbed, with scars of verticillate branchlets at the nodes. This diminutive species was originally found by Mr Matthew in the graphitic shale, associated with the Dadoxylon sandstone, at the southern part of the city of St John. Small fragments of it have subsequently been obtained from the shales of Carlton.

Asterophyllites laxa, sp. nov. Stems very slender and flexuous. Internodes about an inch long. Nodes with about ten long linear one-nerved obtuse leaves an inch or more in length. This form was included in *A. longifolia* in my former paper, but additional specimens

show it to be quite distinct. The Devonian plant-beds of St John are relatively richer in species and individuals belonging to the genus

Fig. 188.—*Asterophyllites, Sphenophyllum, and Lycopodites.*



A, Asterophyllites parvula; (*a*) Branches; (*b*) Leaves enlarged; (*c*) Stem.
B, Sphenophyllum antiquum; (*a*) Magnified; (*b*) Natural size.
C, Lycopodites Matthewi; (*a*) Branch and leaves; (*b, c, d*) Different forms of leaves.

Asterophyllites than any zone of the Coal formation with which I am acquainted. The genus is represented in the Devonian of Europe, and more especially by the fine species *A. coronata* from Thuringia.

Annularia acuminata, Dn. (Fig. 194, G). Leaves oblong, acuminate, one-nerved, six to nine in a whorl, erect or slightly spreading. Whorls usually found disconnected. Detached whorls of this species occur, though rarely, on the surfaces of the shales of Carlton. It seems to be a plant of the same type with *A. sphenophylloides*, Unger, which, according to Lesquereux, occurs in the Coal formation of Pennsylvania. Some specimens show a few whorls attached to each other by a very slender stem.

Sphenophyllum antiquum, Dn. (Fig. 188, B). "Canad. Nat.," vol. vi. p. 170, fig. 7. Leaflets cuneate, one-eighth of an inch wide at the apex, and less than one-fourth of an inch long. Nerves three, bifurcating equally near the base, the divisions terminating at the apices of six obtuse, acuminate teeth. About eight leaves in a whorl. This plant was described from a few detached leaflets from the graphitic shale of St John, which preserved their form and venation in the most wonderful perfection, though they were completely

changed into films of shining graphite. I have since obtained from Mr Hartt a specimen found at Carlton, which, though the individual leaflets are more indistinct, shows their general arrangement in whorls of eight or nine on a slender stem. It is a beautiful symmetrical little plant, quite distinct from any of the species in the Coal measures.

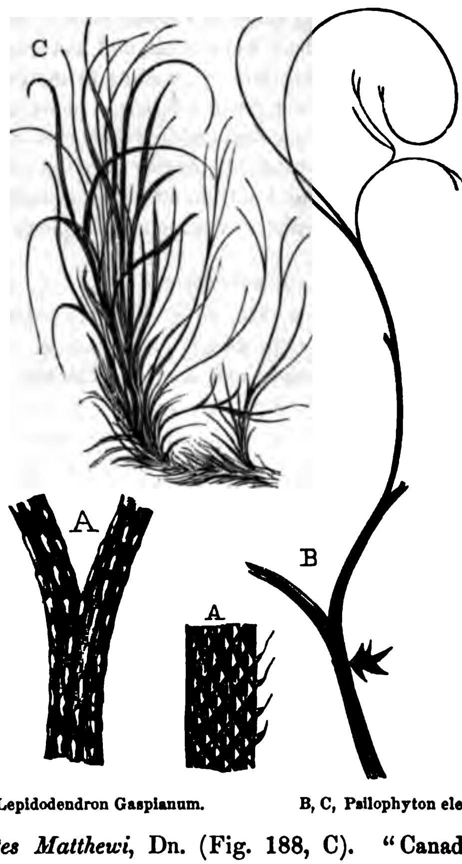
Pinnularia dispalans, Dn. (Fig. 194, L). Smooth slender stems, producing nearly at right angles long branchlets, some of which produce secondary branchlets in a pinnate manner. Stem and branches having a slender vascular axis. This plant was not very dissimilar from some common forms of Carboniferous *Pinnulariæ*. Its main stem must once have been cylindrical, and had a delicate central axis, now marked by a darker line of graphite in the flattened specimens. The branches were not given off in one plane, and also show traces of an axis. There are indications that the stems grew in bundles or groups. It was probably, as has usually been supposed in the case of the species in the Coal formation, an aquatic root or submerged stem of an *Asterophyllites* or some similar plant.

(*Lycopodiaceæ.*)

Lepidodendron Gaspianum, Dn. (Fig. 189, A). Dawson, Quart. Journ. Geol. Soc., vol. xv. p. 483, figs. 3 *a*–3 *d*. This species, originally discovered in Gaspé, and described in my paper on the plants of that locality, was afterwards recognised among the fossils from Perry, and more recently at St John; and numerous and beautiful specimens are contained in Professor Hall's collections from New York State, where the species occur in the base of the Catskill group and in the upper part of the Hamilton group. The varied aspects of the species presented in the numerous specimens thus submitted to me, would, with a less perfect suite of examples, afford grounds for specific or even generic distinctions. Flattened specimens, covered with bark, present contiguous, elliptical, slightly elevated areoles, with an indistinct vertical line and a small central vascular scar (Fig. 189). Decorticated specimens, slightly compressed, show elliptical depressed areoles, not contiguous, and with only traces of the vascular scars In more slender branches the areoles are often elevated at one end in the manner of a *Knorria* (Fig. 189); and in some specimens the areoles are indistinct, and the vascular scars appear as circular spots, giving the appearance presented by the plants named *Cyclostigma* by Haughton. All these forms are, however, merely different states of preservation of the same species. This plant is closely allied to *L. nothum*, Unger, but differs in its habit of growth and in the size of the areoles relatively to that of the branches. The branches were

long and slender, bifurcating rarely, and, unless they were very woody, must have been pendent or decumbent. No large trunks have been seen. It was a widely distributed and abundant species in the Upper and Middle Devonian periods. The plant figured by Professor Rogers in the "Report on Pennsylvania," p. 829, fig. 677, can scarcely belong to any other than this species; and it is also figured in Vanuxem's "Report on New York," p. 191, fig. 55, and p. 157, fig. 38.

Fig. 189.—*Lepidodendron and Psilophyton.*



A, Lepidodendron Gaspianum. B, C, Psilophyton elegans.

Lycopodites Matthewi, Dn. (Fig. 188, C). "Canad. Nat.," vol. vi. p. 171, fig. 8. Leaflets one-veined, narrowly ovate-acuminate, one-tenth to one-fourth of an inch in length, somewhat loosely placed on a very slender stem, apparently in a pentastichous manner. This species was described from specimens found

by Mr Matthew in the graphitic shale in the city of St John. Somewhat larger specimens have since been obtained from the same bed; but I have not seen the plant elsewhere.

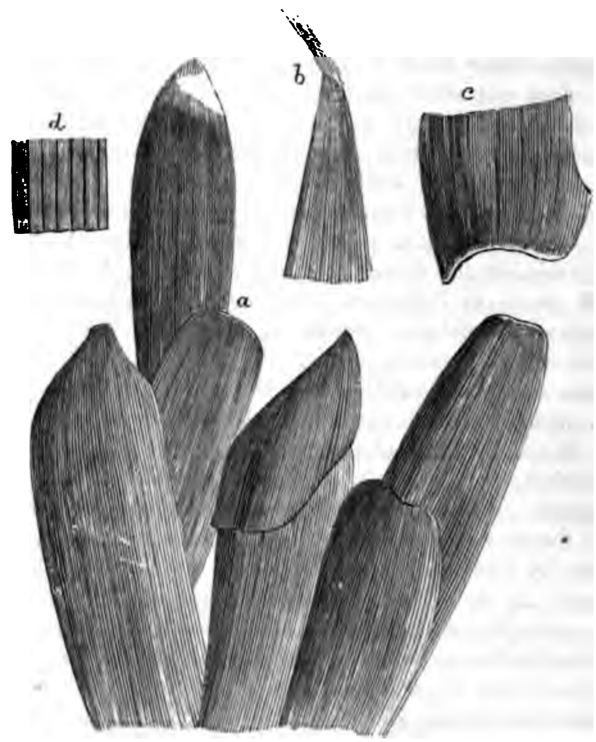
Psilophyton princeps, Dn. Quart. Journ. Geol. Soc., vol. xv. p. 479, figs. 1 *a* to 1 *i*. This remarkable plant, so characteristic of the whole Devonian system at Gaspé, filling many beds with its rhizomes, in the manner of the *Stigmaria* of the Coal measures, and preserved in such abundance and perfection that it is much better know to us in its form, structure, and habit of growth than any other plant of the period, proves, as might have been anticipated, to have had a wide distribution in space as well as in time. Fragments of its stems are distinguishable in the sandstones of Perry, and numerous fine specimens occur among the plants from New York State committed to me by Professor Hall. It occurs in the Hamilton group at Schoharie, New York, and at Akron, Ohio, in the Chemung group at Cascade Falls, and in the Catskill group at Jefferson. Most of the specimens are stems, which show the habit of growth very perfectly. They confirm my inference from the structure of the Gaspé specimens that the plant was woody and rigid, as they often do not lie in one plane, but extend upward and downward in the manner of firm branches buried in sand. Most of the New York specimens seem to have been drifted; but groups of rhizomes, possibly *in situ*, occur in argillaceous sandstone from Fullenham, Schoharie, and in similar beds at Cazenovia and Cascade Falls. These are the only instances presented by Professor Hall's collections of root-beds resembling those of Gaspé. In New York only the Upper and Middle Devonian have as yet afforded land plants; but in Gaspé *Psilophyton princeps* occurs in the Lower Devonian, and fragments which have belonged to it occur in the Upper Silurian.

Psilophyton elegans, Dn. (Fig. 189, B, C). Stems slender, produced in tufts from thin rhizomes, bifurcating and curving at their summits. Surface smooth, with very delicate wrinkles. Fructification in groups of small, broadly oval scales, borne on the main stem below the points of bifurcation. I distinguish this species from *Psilophyton princeps* by its smaller size, its smoother surface, its growth in tufts, and the different form of its organs of reproduction. Still it must be admitted that imperfect specimens could not readily be distinguished from branchlets of *P. princeps*. It was found by Mr Matthew in the shales near Carlton.

Psilophyton (?) *glabrum*, Dn. Smooth, flattened, bifurcating stems, two lines in width, with a slender woody axis. These are objects

of doubtful nature. They must have been stems or roots, bifurcating in the manner of *Psilophyton*, but having a very slender woody axis. They may have been either roots of some plant, or stems of a smooth and comparatively succulent species of *Psilophyton*.

Fig. 190.—*Cordaites Robbii.*



(*a*) Group of young leaves. (*c*) Base of leaf.
(*b*) Point of leaf. (*d*) Venation; magnified.

Cordaites Robbii, Dn. (Fig. 190). Leaves elongated, lanceolate, sometimes three inches wide and a foot in length. Veins equal and parallel. Base broad, clasping the stem, point acuminate. When this species was described in my paper in the "Canadian Naturalist,"* only very imperfect specimens were in my possession; but numerous and fine specimens recently found now enable me more perfectly to characterize the species. The leaves vary much in form; and

* May 1861, p. 168.

in their young state, as represented in Fig. 190 *a*, were often of a regularly oblong form. They have numerous equal parallel nervures, which were probably fibro-vascular, like those of Ferns, as they present precisely the same appearance as the nervures of the plants of this family preserved with them, and which, in these beautiful graphitized specimens, are traced in deeper lines of graphite than the film of the same material which represents the intervening parenchyma. In the best preserved specimens, the leaf is quite smooth; but in some the space between the nervures rises into little ridges, so as to give a striated appearance. These different aspects, however, often occur on different portions of the same leaf. The present species so closely resembles *C. borassifolia* of the Coal formation that it might readily be mistaken for it; but it differs somewhat in the form of the leaf, and still more in the venation, the nervures in the present species being perfectly *equal.**

In the paper already referred to, I have stated at length my reasons for preferring, in the case of this plant and *C. borassifolia*, the generic name *Cordaites*, to *Poacites*, *Flabellaria*, and *Nœggerathia*, all of which have been applied to such plants, together with others having no affinity to them. To the name *Pychnophyllum*, proposed by Brongniart, this objection does not apply; but *Cordaites*, I believe, has priority, and is due to the describer of the typical species.

I associate the genus *Cordaites* with Lycopodiaceous plants without hesitation, notwithstanding the peculiar character of its foliage, because Corda has shown that its stem is strictly acrogenous in structure, and of the same type with those of *Lomatofloyos* and *Ulodendron*—a fact which excludes it alike from association with Monocotyledonous plants and with Ferns. (See Chap. XX., *supra.*)

It is worthy of notice that, while the leaves of *Cordaites*, unlike those of *Sigillaria* and *Lepidodendron*, were not attached by narrow bases, but clasping, they were still, like those of nearly all other Devonian and Carboniferous plants, deciduous and capable of disarticulation, as is proved by the immense abundance of fallen leaves, while the stems, probably remaining attached to the soil, are rare. It is further to be observed that these leaves were rigid, and long resisted decomposition; on which account, no doubt, they formed a favourite base of attachment for the little *Spirorbes* which swarmed both in the Devonian and Carboniferous Periods. At St John, many of these leaves are covered with these little shells.

* The nervures in *C. borassifolia* are alternately thick and thin; but there is another species in the *Upper* Coal measures of Nova Scotia which has equal nervures.

The leaves of the present species are very abundant in the shales of the vicinity of St John, and indeed are eminently characteristic of them; and on this account I regard the dedication of it to my late lamented friend, Dr Robb, as specially appropriate. I have

Fig. 191.—*Cyclopteris Jacksoni.*

(*a* and *b*), Pinnules showing venation.

not recognised this plant in the specimens from Gaspé or Perry; and the only indication of it in the New York collection is a fragment of a leaf from the Hamilton group of Cazenovia, New York, not sufficiently perfect to render its identification certain.

Cordaites angustifolia, Dawson. Leaves linear, much elongated, one-tenth to one-fourth of an inch broad, with delicate, equal, parallel

nervures. This species, originally described from specimens collected at Gaspé where it abounds in the roof of the little Devonian coal-seam, occurs also at St John, and in the Marcellus Shale of New York; and it has also been found by Sir W. E. Logan in the *Upper Silurian* of Cape Gaspé, together with fragments of the rhizomes of *Psilophyton*. It usually occurs as long riband-like detached leaves, not always easily distinguishable from the flattened stems and roots of other plants found in the same beds. I have not seen the apex nor the base of the leaf, but among Professor Hall's specimens from the Marcellus Shale is one which appears to consist of the remains of several leaves, attached to a short stem, of which the structure and markings have perished.

Plants closely resembling this are described by Unger and Goeppert, from the Devonian of Europe; but the characters given do not enable me to identify any of them with the present species. Such plants are placed by those writers in the genus *Nœggerathia*, which I reject for the reasons above stated.

(*Filices.*)

Cyclopteris Jacksoni, Dawson (Fig. 191). "Canad. Nat." vol. vi. p. 173, fig. 9. "Frond bipinnate; rachis stout and longitudinally furrowed; pinnæ alternate; pinules obliquely obovate, imbricate, narrowed at the base, and apparently decurrent on the petiole; nerves nearly parallel, dichotomous; terminal leaflet large, broadly obovate or lobed." This species, first described, in my paper in the "Canadian Naturalist," from a specimen found at Perry, occurs also in small fragments at St John, and large specimens occur in the collection of Professor Hall from the Old Red Sandstone of Montrose, New York. It is closely allied to *C. Hibernica*, and is its American representative. It would be placed by many botanists in the genus *Adiantites* of Brongn., but this name is objectionable in the case of Ferns evidently not related to *Adiantum*.

Cyclopteris obtusa, Lesquereux (Fig. 192, A). To this species, described by Lesquereux, from the Old Red Sandstone of Pennsylvania, I refer a beautiful Fern not unfrequent in the shales near St John. Lesquereux places it in the genus *Nœggerathia*, a name applied by other botanists to a very different group of plants.

Cyclopteris valida, Dawson (Fig. 192, B). Tripinnate; primary divisions of the rachis stout and wrinkled. Pinnæ regularly alternate. Lower pinnules nearly as broad as long, deeply and obtusely lobed, narrowed and decurrent at the base; regularly diminishing in size and breadth toward the point, and the last pinnules narrowly obovate and confluent with the terminal pinnule. Nerves delicate, several

Fig. 192.—*Devonian Ferns.*

A, Cyclopteris obtusa.
B, Cyclopteris valida, and pinnule enlarged.
C, Neuropteris polymorpha, terminal pinnules.
D, Sphenopteris marginata, and portion enlarged.
E, Sphenopteris Harttii.
F, Sphenopteris pilosa.
G, Hymenophyllites curtilobus.
H, Hymenophyllites Gersdorffii, and portion enlarged.
I, Alethopteris discrepans.
K, Pecopteris serrulata.
L, Pecopteris preciosa.
M, Alethopteris Perleyi.
N, Hymenophyllites subfurcatus.

times dichotomous. This is one of the most perfect and beautiful of the St John Ferns. It resembles at first sight *Sphenopteris macilenta*, L. and H.; but on examination it differs materially in details. It is an elaborate and ornate example of the peculiar type of *Cyclopteris* already referred to as characteristic of the Upper Devonian Period.

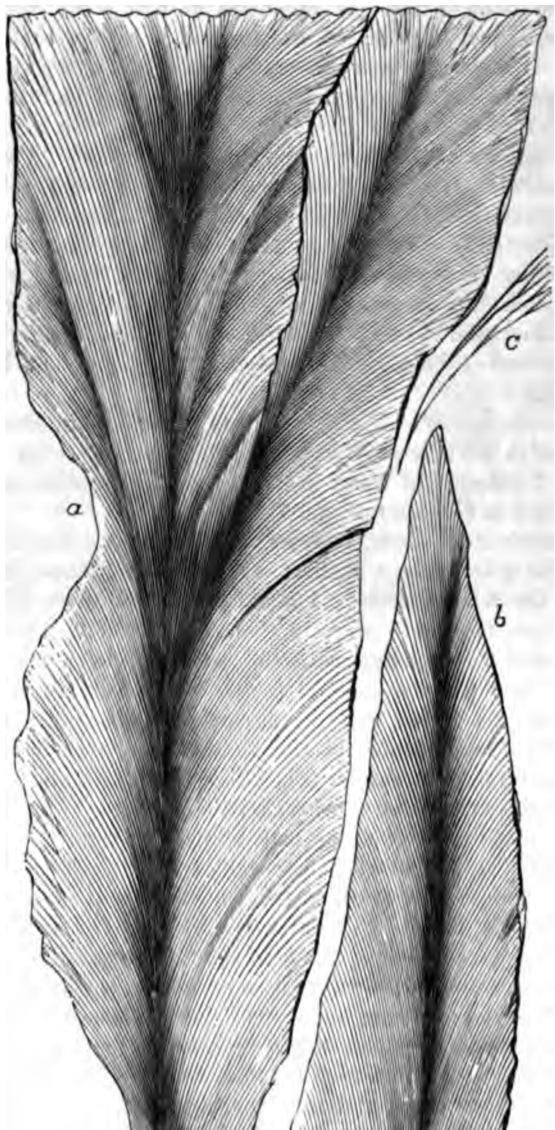
Cyclopteris varia, Dawson. Pinnate (or bipinnate). Pinnæ with a thick petiole. Pinnules decreasing in size to the terminal one, which is ovate and lobed. Pinnules oblique, decurrent on one side. Nerves frequently dichotomous. This Fern has been found only in fragments. It seems to have been a thick fleshy frond, but the specimens are insufficient to show its habit of growth. Its nearest allies seem to be *C. Villiersi*, Sternberg (*Neuropteris Villiersi*, Brongn.), and *Cyclopteris heterophylla*, Goeppert; but it differs from both.

Cyclopteris, s. n. (?) Many fragments occur in Mr Hartt's collections of a very large *Cyclopteris* which may possibly have resembled *C. Brownii* of Perry in Maine, but the specimens are not sufficient for its full description.

Cyclopteris Bockshiana, Goeppert. Fragments referable to this species (if it is really a distinct species from *C. obtusa*), are found rarely in the St John shales. I retain the generic name *Cyclopteris* for all these ferns, so eminently characteristic of the Devonian as distinguished from the Carboniferous; not that I have any certainty that they belong to one natural genus, but because they resemble each other in venation, and the attempts to arrange them in such genera as *Adiantites* and *Nœggerathia* are evidently injudicious.

Neuropteris polymorpha, Dawson (Fig. 192, C). Pinnate or bipinnate. Rachis or secondary rachis irregularly striate. Pinnules varying from round to oblong, unequally cordate at base, varying from obtuse to acute. Terminal leaflet ovate, acute, angulated or lobed. Midrib delicate, evanescent. Nervures slightly arcuate, at acute angles with the midrib. This fern is very abundant in the shales near Carlton, at St John. At first sight it appears to constitute several species, but careful comparison of numerous specimens shows that all the various forms may occur on the same frond. In its variety of forms it resembles *N. heterophylla*, Brongn., or *N. hirsuta*, Lesquereux; but it differs from the former in its delicate midrib and acutely angled nervures, and from the latter in its smooth surface. In the more recent collections of Mr Hartt there are very fine and perfect examples which I hope at some future time to figure. The fragment here figured is a part of a terminal pinna.

Fig. 193.—*Neuropteris Dawsoni.**



(*a*) Fragment of pinna. (*b*) Point of pinnule. (*c*) Venation.

* The Midrib is not accurately given in this figure.

Neuropteris Dawsoni, Hartt (Fig. 193). This remarkable fern, discovered by Mr Hartt, and to which he has done me the honour to attach my name, presents curious points of affinity to Cyclopterids and Neuropterids, and perhaps may, when more fully known, be placed in a distinct genus. Mr Hartt describes it as follows:—

"Frond, pinnate or bipinnate (most probably the latter); rachis thick, sometimes when compressed half an inch wide, coarsely striated, always winged; pinnæ (pinnules?) alternate, very oblique, linear lanceolate, moderately acute at apex, slightly notched above its base, decurrent on the rachis, often about an inch in width, and sometimes six inches long; margin strong, a few large undulations; midrib thick, tapering gradually, disappearing before reaching the apex, straight, entering a pinna (pinnules?) obliquely from the upper side, giving off very numerous nerves, which spring very obliquely from it, running about parallel with it, forking once near the midrib, and once more half-way to the margin, sometimes again close to the margin, the whole series being strongly arched.

"The pinnæ, particularly when the midribs are thick, show a strong tendency to split up in a direction to the rachis. I have sometimes noticed them folded in a conduplicated manner."

Neuropteris crassa, sp. nov. Single pinnules, broad, oval, oblique at base, thick, smooth above with very numerous arched veins. A pinna with somewhat larger pinnules similarly veined may belong to the same species.

There are fragments which possibly indicate two other species of *Neuropteris*.

Sphenopteris Hœninghausi, Brongniart. One of the ferns from the shales near St John appears to be identical with the above species, which belongs to the Lower Carboniferous of Europe.

Sphenopteris marginata, Dawson (Fig. 192, D). This resembles the last species in general form, but is larger, with the pinnules round or round-ovate, divided into three or five rounded lobes, and united by a broad base to the broadly winged petiole. Found with the preceding. One specimen, given to me by Mr Hartt, shows a frond six inches in length.

Sphenopteris Harttii, Dawson (Fig. 192, E). Bipinnate or tripinnate. Divisions of the rachis margined. Pinnules oblique, and confluent with the margins of the petiole; bluntly and unequally lobed. Nerves small, oblique, twice-forked. This beautiful fern very closely resembles *S. alata* from the Coal-field of Port Jackson, but differs in several of its details. I name it in honour of Mr Hartt, the discoverer of several of the St John ferns. Found with the preceding.

Sphenopteris Hitchcockiana, Dawson. Doubtful fragments only occur.

Sphenopteris pilosa, sp. nov. (Fig. 192 F). Bipinnate or tripinnate, pinnæ oblong, with crowded, obovate, decurrent, pinnules, with a few forking veins. Terminal leaflet, broad, obtuse, surface thickly covered with minute hairs, which generally mask the venation. I refer this curious fern to *Sphenopteris* with much hesitation, but I think its venation places it there in the present state of our classification, though in general aspect it rather resembles a *Neuropteris* or *Cyclopteris*. It has some points of resemblance to the Carboniferous fern *Sphenopteris decipiens*.

Hymenophyllites curtilobus, Dawson (Fig. 192, G). Bipinnate. Rachis slender, dichotomous, with divisions margined. Leaflets deeply cut into subequal obtuse lobes, each one-nerved, and about one-twentieth of an inch wide in ordinary specimens. According to Lesquereux, the genus *Hymenophyllites* is characteristic in America of the Upper Devonian. In Europe it is represented also in the Lower Coal. I have seen only one or two species in the Carboniferous rocks of Nova Scotia or New Brunswick. The present species resembles a gigantic variety of *H. obtusilobus*, Goeppert (*Sphenopteris trichomanoides*, Brongn.).

Hymenophyllites obtusilobus, Goeppert. Found with the preceding.

Hymenophyllites Gersdorffii, Goeppert (Fig. 192, H). Found with the preceding.

Hymenophyllites subfurcatus, sp. nov (Fig. 192, N). This species is among Mr Hartt's recent collections. It is of the type of *H. furcatus*, which, according to Lesquereux, is found in the Devonian of Pennsylvania, but it differs in its broader and acute divisions.

Alethopteris discrepans, Dawson (Fig. 192, I). Bipinnate. Pinnules rather loosely placed on the secondary rachis, but connected by their decurrent lower sides, which form a sort of margin to the rachis. Midrib of each pinnule springing from its upper margin and proceeding obliquely to the middle. Nerves very fine and once-forked. Terminal leaflet broad. This fern so closely resembles *Pecopteris Serlii* and *P. lonchitica* that I should have been disposed to refer it to one or other of these species but for the characters above stated, which appear to be constant. *P. Serlii* is abundant in the Lower Carboniferous of Northern New Brunswick, and *P. lonchitica* is the most common fern throughout the whole thickness of the Joggins Coal measures; but in neither locality does the form found at St John occur. On this account I think it probable that the latter is really distinct. In Murchison's "Siluria," 2d edition, p.

321, a fern from Colebrook Dale is figured as *P. lonchitica*, which, so far as I can judge from the engraving, may be identical with the present species. Locality, St John.

Alethopteris ingens, Dawson. Pinnules more than an inch wide, and three inches or more in length, with nervures at right angles to the midrib and forking twice. Only a few fragments of pinnules of this species have been found in the shales near St John. They are usually doubled along the midrib, as if it had been their habit to be folded in a conduplicate manner. Their general aspect suggests a resemblance to the Mesozoic Tæniopterids rather than to the Pecopterids of the Coal formation.

Pecopteris (*Alethopteris*) *obscura* (?), Lesq. Mr Hartt has recently sent to me, from St John, a pinna of a *Pecopteris* having oblong, obtuse pinnules attached by the whole base, with a slender midrib, and slightly repand edges. The nervures are not preserved. It closely resembles *A. obscura*, Lesquereux, from the Coal of Pennsylvania.

Pecopteris (*Alethopteris*) *serrulata*, Hartt (Fig. 192, K). This species is, I believe, the same with *Neuropteris serrulata* of a former paper, the imperfect specimens in my possession causing me to refer it to that genus. Mr Hartt, however, has found specimens which enable him to correct this error. I retain the specific name to prevent confusion of terms, though there are already species of *Pecopteris* known as *serrula* and *serrata*. The present species approaches closely to *P. plumosa* of Brongn., but differs in its more distant pinnules, not connate at the base, with the veins not forking at the margin, and the midrib more oblique and decurrent on the rachis. It resembles rather less closely *P. serra*, L. and H., and *P. delicatula* and *dentata* of Brongn., and may be regarded as the Devonian representative of this group of small-leaved Pecopterids. It is thus described by Mr Hartt:—

"Tripinnate, pinnæ short, alternate, close or open, lanceolate, very oblique, situated on a rather slender rounded subflexuose rachis; pinnules small, linear lanceolate, crenulate, revolute, moderately acute, oblique, sessile decurrent, widest at the base, open, separated from one another by a space equal to the width of a pinnule, slightly arched towards the point of pinna; longest at base of pinna, decreasing thence gradually to the apex; terminal pinnule elongated. Median nerve entering the pinnule very obliquely, flexuous, running to the apex. Nervules very few, oblique, simple, and somewhat rarely forking at the margin."

Pecopteris (*Alethopteris*) *preciosa*, Hartt (Fig. 192, L). Pinnæ a little larger than those of the last species, not serrated; placed nearly

at right angles to the rachis, obtuse, narrow toward the extremity, suddenly widened or almost auriculate at the lower side; midrib extending to the apex; nerves few, at a somewhat acute angle.

Alethopteris Perleyi, Hartt (Fig. 192, M). "This species resembles *Alethopteris serrula* of Lesqx. It differs from it in the following points:—The pinnæ are wider and closer, and not so long; the pinnæ are usually tridentate. The teeth acuminate, the middle one sometimes emarginate. The vein is three-forked, sending a veinlet into each lacinia. The middle veinlet branches in the middle lacinia. In *A. serrula* the pinnules, or, as Lesqx. terms them, the *lobes*, are united more than half the way up. *A. Perleyi* has the pinnules united only one-third of the way; and whereas in the former they are divided by a sharp gash, in the latter they are divided by a deep rounded sinus.

"Dedicated to the late M. H. Perley, Esq., H.M. Commissioner of Fisheries and Vice-President of the Natural History of St John."

(*Incertæ sedis.*)

Cardiocarpum cornutum, Dawson (Fig. 194, A). Broadly ovate, emarginate at base, dividing into two inflexed processes at top. A mesial line proceeds from the sinus between the cusps, downward. Nucleus more obtuse than the envelope, and acuminate at the top. Surface of the flattened envelope striate, that of the nucleus more or less rugose. Length about seven lines. Numerous in shale near St John. The specimens are all perfectly flattened, and many of them are also distorted, being elongated or shortened according to the direction in which they lie in the shale. The nucleus constitutes a strongly shaded spot of graphite. The flattened envelope appears as a less distinct wing or border.

Cardiocarpum obliquum, Dawson (Fig. 194, B). Unequally cordate, acuminate, smooth, with a strong rib passing down the middle; length about three lines. Found with the preceding. It somewhat resembles some of the forms of *C. acutum*, L. and H.

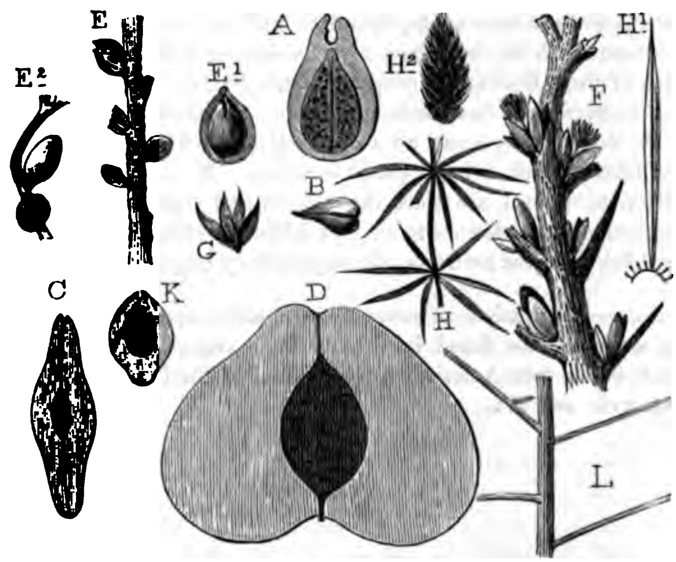
Cardiocarpum Crampii, Hartt (Fig. 194, C). Elongate, slightly expanding at the middle, obtuse at base, obtuse or emarginate at apex, length one inch, greatest breadth ·25 inch; nucleus small, central, oval, connected by a median line with the extremities; surface of margin slightly rugose. This fruit may at once be recognised by its resemblance to the samara of an ash. It is dedicated to Mr Cramp of St John, a zealous collector of the Devonian plants.

Cardiocarpum Baileyi, sp. nov. (Fig. 194, D). This species, discovered by Mr Hartt, is the largest and most beautiful of these winged fruits as yet afforded by the Devonian. It is broadly cordate

and emarginate at the apex, 1·5 inch broad, and one inch long, with a large broadly oval acuminate nucleus, and the usual mesial line.

We have thus four distinct species of these mysterious winged seeds from the Devonian. They must have been fruits of trees, but whether of phænogams, or enormous winged spore cases of some cryptogamous plant, is uncertain. Their marginal wings show no venation whatever, though preserved in shales which show very well the venation of ferns. The margin must have been membranous, and the nucleus thick and dense, that part appearing as a comparatively strong graphitic film, while the wing or margin is excessively tenuous.

Fig. 194.—*Devonian Fruits, etc.*



A, Cardiocarpum cornutum.
B, Cardiocarpum acutum.
C, Cardiocarpum Crampii.
D, Cardiocarpum Baileyi.
E, Trigonocarpum racemosum.
(E1, E2.) Fruits enlarged.
F, Antholithes Devonicus.
G, Annularia acuminata.
H, Asterophyllites acicularis. (H1), Leaf.
H2, Fruit of the same.
K, Cardiocarpum (? young of A).
L, Pinnularia dispalans.

Trigonocarpum racemosum, Dawson (Fig. 194, E). Ovate, obtusely acuminate, in some specimens triangular at apex. In flattened specimens the envelope appears as a wing. Attached in an alternate manner to a thick, flexuous, furrowed rachis. This is evidently a fruit or seed, borne in a racemose manner on a stout rachis. In some specimens the seeds are close to each other, in others more

remote. Attached to some are apparently traces of calyx-leaves or bracts. Shales of St John.

Antholithes Devonicus, sp. nov. (Fig. 194, E). Stipe thick, rugose; flowers distichous, somewhat distant, each with a strong, straight spine or bract, and several broader scales. In some specimens a number of slender threads (filaments or styles) are seen to project from between the scales. This fossil is evidently of the same general character with the *Antholithes* of the Coal formation.

I have to add to the above descriptions the remark, that I have been unable to figure the larger and finer ferns and other fossils of St John in a manner worthy of them. I have given merely such fragments as will aid in their identification. I trust that now, when so extensive collections have been made, the means will be found to figure the finer specimens. In the meantime, after examining with care twelve large cases of these fossils, the property of the Natural History Society of New Brunswick, I have arrived at the conclusion that we have nearly all the material necessary for a full illustration of most of the species, —a labour which I hope yet to complete. In examining this large collection, while I see much that throws new light on the species, it is a source of satisfaction to me that I have to retract so little of what I published on the evidence of comparatively imperfect material.

Note.—Illustrations of several of the above species not figured in this work, will be found in the Author's papers on the Devonian plants of Eastern America in the Journal of the Geological Society, vols. xviii. and xix.

CHAPTER XXIII.

THE UPPER SILURIAN.

UPPER SILURIAN OF NOVA SCOTIA—OF NEW BRUNSWICK—USEFUL MINERALS—FOSSIL REMAINS—METAMORPHISM OF SEDIMENTS—IGNEOUS ROCKS.

THAT enormous mass of sediments constituting the Silurian system of Sir Roderick Murchison, is by some geologists divided into three portions—the Upper, Middle, and Lower. As will be seen, however, by reference to the table of geological cycles on p. 137, in North America this great system of formations represents *two* entire geological cycles, and no more. One of these has been named the *Upper* and the other the *Lower* Silurian; though, in accordance with ordinary geological nomenclature, each of these great groups, co-ordinate in importance with the Devonian and Carboniferous, might have a distinct name. The illustrious author of "Siluria" has not, in his latest edition (1867), claimed for the Silurian rocks this distinction of constituting two systems; but he has recognised the term Primordial, proposed by Barrande, in so far as to designate the lowest members of the system as "Primordial Silurian." While, however, the term Silurian as thus held includes *two* great cycles of the earth's history, the term Primordial is to be understood in a limited sense, since the only truly Primordial rocks are the Laurentian, or those still older sediments from which the materials of the Laurentian have been in part derived.

Acadia cannot, however, claim to be a typical region for any of these series of rocks, presenting them but in limited areas, and so much altered and disturbed, that their arrangement and subdivisions are by no means so clear as in the great inland plains of North America. We may therefore in this work rest content with the present nomenclature, and proceed to consider the Upper Silurian as developed in Nova Scotia and New Brunswick.

1. *Upper Silurian of Nova Scotia.*

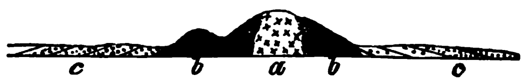
On consulting the map, it will be observed that I have coloured as Upper Silurian certain areas in Cape Breton, more particularly in the eastern and northern parts; a very irregular hilly tract in Eastern Nova Scotia, commencing at Cape Porcupine and Cape St George, and extending toward the Stewiacke River; the long narrow band of the Cobequid Mountains; and a belt of variable width skirting the northern side of the older or Lower Silurian metamorphic district in the western counties. The area occupied by these rocks includes the highest land and the principal watersheds of Nova Scotia.

Owing to the alteration and disturbance to which its rocks have been subjected, the structure of this district is much more complicated than that of those which have been described above, and its interior position causes it to present fewer good sections to the geologist. For these reasons less attention has been devoted to it than to the Carboniferous districts, and the details of its structure are comparatively little known. In describing it, however, I shall endeavour to follow the method previously pursued, by attending somewhat minutely to some of the best and most instructive exposures in coast and river sections, and applying the information obtained from these to the elucidation of the true relations and structure of the remaining portions. I shall then describe the important deposits of useful minerals which occur in this group of rocks, and their fossil remains. In this order of proceeding, it will be convenient to study first the development of the formation in Eastern Nova Scotia, and to proceed westward, returning afterward to the Island of Cape Breton.

At *Cape Porcupine* the igneous and metamorphic rocks come boldly out upon the Strait of Canseau, in a precipice 500 feet in height, and afford a good opportunity of studying these rocks and their relations to the Carboniferous system. The central part of Cape Porcupine is a mass of reddish syenite, consisting principally of red felspar and hornblende. This once molten mass passes by gradual changes into hard flinty slates, which, in shattered and contorted layers, lean against its sides, and on these again rest beds of conglomerate, forming the base of the Carboniferous series, and made up of pebbles of syenite and flinty slate, like those of the cape itself. Here we can plainly read the following history:—*First*, Beds of mud deposited in the sea, probably in the Upper Silurian period. *Secondly*, These beds upheaved and metamorphosed by the injection of the molten syenite. *Thirdly*, Large portions of the altered and igneous rock ground up into pebbles by water, and scattered over the sea-bottom to form the lowest layer

of a new geological formation, the same that we have studied in preceding chapters. The structure of Cape Porcupine is represented in Fig. 195.

Fig. 195.—*Arrangement of Syenite, Slate, and Conglomerate at Cape Porcupine.*



(*a*) Syenite. (*b*) Slate. (*c*) Conglomerate and Sandstone.

At Cape Porcupine the altered rocks of the group now under consideration occupy less than three miles of the coast section, and are separated by Carboniferous rocks and by Chedabucto Bay from the eastern extremity of the older metamorphic district of the Atlantic coast, distant about twenty-four miles. As Cape Porcupine affords no fossils, and can therefore tell nothing of the condition of the earth and its inhabitants at the time when these slates were deposited, we may proceed to trace the continuation of its rocks into the interior.

From Cape Porcupine, the southern margin of the metamorphic rocks extends along the northern side of the Carboniferous district of Guysborough for about sixty miles, when it meets the Lower Silurian rocks of the coast. In several places along this line, igneous action appears to have continued or to have recurred as late at least as the Coal formation period. This is testified by the condition of the Lower Carboniferous rocks in many places near Guysborough, westward of which place a considerable promontory of altered and igneous rocks extends to the southward, nearly across the Carboniferous district.

The northern margin of the band, commencing at Cape Porcupine, may be traced to the westward about forty miles, when it unites with a broader but very irregular promontory of similar rocks extending toward Cape St George. Between these two bands is included the Carboniferous district of Sydney County. The tract formed by their union is the widest extension of these rocks in the province.

The metamorphic promontory extending to Cape St George, and including the Antigonish and Merigomish Hills, attains a greater elevation than the band connected with Cape Porcupine. At its extremity, however, it becomes divided into a number of detached hills and ridges, separated by Lower Carboniferous beds, to which in some cases the metamorphic action has extended itself. The Antigonish and Merigomish Hills contain large masses of syenite, porphyry, compact felspar, and greenstone, associated with slates and quartzite.* On their western side, near Arisaig, there is a patch of shale, slate,

* Quartzite is a flinty rock produced by the hardening and alteration of sandstone.

and thin-bedded limestone, with fossil shells, and but very little altered, to which we must return in the sequel in a more particular manner.

The northern boundary of the broad band of metamorphic and hypogene rocks, formed by the union of the two promontories already noticed, extends in a westerly direction along the south side of the Pictou Carboniferous district, until it reaches the east side of the East River of Pictou, when it suddenly bends to the south, allowing the Carboniferous strata to extend far up the valley of that river. Here, as at Arisaig, its margin includes fossiliferous slates, among which is a thick bed of iron-ore including fossil shells. With respect to these fossils, I may remark that they are all marine, that they belong to numerous genera and species, and that they are all of distinct species from those of the formations before mentioned, there being a decided break between the fauna of the Upper Silurian and that of the Devonian period, and of course the Carboniferous fauna is still more remote in its characters.

Both at Arisaig and the East River excellent opportunities are afforded for studying the contrast between the Upper Silurian and the Carboniferous. The collector may, in the shales of Arisaig or the slates of the East River Hills, collect a great number of marine species, some of them in a fine state of preservation, others distorted and partly defaced by the partial alteration of the containing rocks. At both places he can observe that the rocks containing these fossils have been tilted up and hardened before the lowest beds of the Carboniferous system were deposited. At both places he can find in these overlying Carboniferous rocks abundance of fossils, also marine, *but entirely distinct from those of the older group.* He thus finds that, in passing from one of these formations to the other, he has passed from one great period of the earth's history to a subsequent one, in which no trace remained of the animal population of the former. He has entered, in short, on a new stage of the creative work.

Immediately on the east of the East River, the metamorphic band is about fifteen miles in breadth, and includes masses and dikes of syenite and greenstone, and beds of quartzite and slate, the latter of very various colour and texture. Beyond the East River, the metamorphic band again widens; and between the upper part of the Middle River of Pictou and that of the west branch of the St Mary's River (the point to which we have already traced its southern boundary) it forms a broad and irregular tract of metamorphic country. Westward of this tract it becomes narrower, and, after extending between the Stewiacke and Salmon Rivers, sinks beneath the Carboniferous beds, while a group of detached masses of igneous and altered rock,

extending through Mount Thom, imperfectly connects it with the eastern extremity of the Cobequid range of hills. In the hilly country connected with Mount Thom, and in the vicinity of the upper parts of the Salmon, West, and Middle Rivers, considerable breadths of Lower Carboniferous strata have been partially metamorphosed, and invaded by greenstone and other igneous rocks. It is also quite possible that portions of the rocks here cropping out from beneath the Carboniferous may be Devonian. A mass of granite, containing dark gray felspar, abundance of black mica, and very little quartz, occurs on the east side of Mount Thom. This is the only instance, so far as I am aware, of the occurrence of true granite in this group of rocks in this part of Nova Scotia.

The Cobequid Hills, extending nearly in an east and west direction for about ninety miles, in that part of Nova Scotia lying north of the southern arm of the Bay of Fundy, must be referred to the metamorphic group now under consideration. Both their stratified and igneous rocks are similar to those of the parts of this group already described. Fossils are absent or very rare in those parts of them which I have explored, with the exception of Earlton, in the eastern extremity of the range, where there are slates containing fossils similar to those already noticed. I shall make no attempt to describe the numerous and singular varieties of altered and igneous rocks found in the Cobequid range, but shall content myself with a description of its structure in its central portion, which is illustrated by the general section attached to the map.

On the northern side of the hills, near the post road from Truro to Amherst, and also on Wallace River, the lowest rocks of the Carboniferous system, consisting of reddish-brown conglomerates, are seen at the base of the hills. Their dip is to the northward at a high angle. On ascending the hills, masses of red, flesh-coloured, and gray syenite are seen, and rise rapidly to the height of several hundred feet; the northern side of the range being steeper and more lofty than the southern. The syenite of this part of the hills has often been described as a granite; but wherever I have observed it, it is a true syenite, containing reddish or white felspar, black hornblende, and nearly colourless quartz. Some of the red varieties are large grained and very beautiful. The gray varieties are often fine grained, and appear to pass into greenstone.

It is remarkable that the syenite and greenstone of this part of the mountain are traversed by numerous small veins of true granite. Whether these have been produced by segregation, or are parts of a later outburst of granitic rock, I cannot determine with certainty, but

think the latter more probable. I am not aware that any masses of true granite occur here. It is, however, quite possible that after or during the cooling of the syenite, veins may have been injected into it from granitic masses below, which have not reached the surface.

Penetrating further into the range, we find thick beds of dioritic rock associated with slate and quartzite, of a great variety of colours and textures. There appear to be also dikes of greenstone at some points, penetrated by a network of syenitic or felspathic veins. The general course of the greenstone dikes coincides with that of the range of hills. Toward the southern side of the hills, gray quartzite, and gray, olive, and black slate prevail, almost to the exclusion of igneous rocks. The strike of these beds is nearly S.W. and N. E., with high dips to the southward. On the south they are bounded and overlaid unconformably by Carboniferous conglomerate and sandstone.

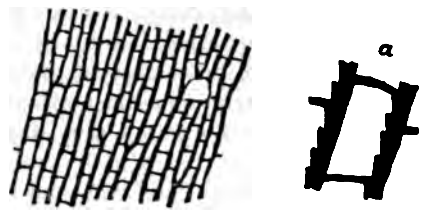
The structure observed in this part of the chain appears to prevail throughout; the syenitic rocks forming a broad band on the northern side, and slate and quartz rock with dikes of igneous rock, probably of later date than those on the north side, occurring on the southern ridges. The only exception to this that I am aware of is at the extreme eastern end, where the igneous rocks are less massive and the syenite disappears.

The Cobequid range presents a succession of finely wooded and usually fertile ridges; and the chain is very continuous, though broken by some narrow transverse ravines. Many of the streams flowing from these hills plunge downward in fine cascades at the junction of the hard rocks with the softer Carboniferous beds. The most remarkable of these waterfalls on the south side is that of the Economy River, on the north side that of the principal branch of Waugh's River.

Passing from the Cobequid Mountains to the *Slate hills of the south side of the Bay*, in King's County, we find slates not very dissimilar from those of the Cobequids, in the promontory northward of the Gaspereaux River. Here the direction both of the bedding and of the slaty structure is N. E. and S.W.; but the planes of cleavage dip to the S.E., while the bedding, as indicated by lines of different colour, dips to the N.W. These slates, with beds of quartzite and coarse limestone, are continued in the hills of New Canaan, where they contain crinoidal joints, fossil shells, corals, and in some beds of fawn-coloured slate beautiful fan-like expansions of the pretty *Dictyonema* represented in Fig. 196. Very fine specimens of this fossil were found by the late Dr Webster of Kentville. It was the habitation of thousands of minute polypes, similar apparently to those of the modern *Sertularia*. The general strike of the rocks in New

Canaan is N.E. and S.W., and they extend from that place westward to the Nictaux River. Westward of Nictaux River, as already mentioned in describing the Devonian, the beds of the Upper Silurian, as

Fig. 196.—*Dictyonema Websteri.*



(*a*) Portion enlarged.

well as those of the last mentioned formation, are interrupted by great masses of granite, which form the hills along the south side of the Annapolis River, from a place called Paradise to Bridgetown, and with some interruptions nearly as far as the town of Annapolis. This granite is hardly distinguishable in its character from that of the south coast of the province, except that it is perhaps more felspathic, and less largely and perfectly crystalline. Its age, as already stated, must be that of the newer Devonian or older Carboniferous. Near Paradise it is traversed by veins of reddish compact felspar, with crystals of schorl and transparent smoky quartz. The latter mineral is found in very large and beautiful crystals scattered in the surface rubbish, and is collected and sold by the inhabitants.

Westward of Paradise, I have not traced the equivalents of the Upper Silurian; the Devonian beds, as already stated, appearing at Moose and Bear Rivers. At the Joggin near Digby, the slates, probably of this series, are broken up and much altered by masses or dikes of porphyritic rock. At one place here I found the strike of the bedding to be N. 15° E., while that of the slaty structure is N. 45° E. Westward of this place the slates in a highly metamorphic condition continue with general N. E. and S.W. strike to the coast of Clare, where a considerable breadth of country is occupied with olive and gray slates, quartz rock, and occasional dikes of greenstone. At Montengan these beds include veins of iron pyrites, one of them a foot in thickness. I have not been able to observe the junction of the group now under consideration with the metamorphic district of the Atlantic coast; but I think it probable that the limit of the altered Upper Silurian rocks in this direction is near Beaver River.

With respect to the age of these rocks, it is certain that the fossil-

iferous parts are Upper Silurian. Some portions of the altered rocks may, however, be either Devonian or Lower Silurian. The first upheaval and alteration of the beds must have occurred long before the beginning of the Carboniferous period, but igneous action continued, especially in the eastern part of the province, during and perhaps after that period. In their original state these slates and quartz rock, and their iron ore, must have been shales, sandstone, and iron sand, abounding in fossil remains, and with layers of calcareous matter mostly made up of shells and corals. Over large tracts the fossils have been obliterated by metamorphism, and a perfect slaty structure has been induced.

In Cape Breton, rocks similar to those above described constitute the several irregular tracts of metamorphic and igneous country to which the colour of this group has been assigned. Syenite and porphyry are extensively developed in a line extending from St Peter's along the east side of the Bras d'Or, in the country between little Bras d'Or and the East Arm, in the high ridge extending to Cape Dauphin, in the hills near the Bedeque, Middle, and Margarie Rivers, in those near Mabou, and in the irregular tract at the sources of the Inhabitants River, and River Denys. Slates are associated with them in these places, but I am not aware that they contain any fossils.

I am informed by Mr Brown that the elevated region occupying the extreme northern part of Cape Breton, and of which I have seen only the southern borders, consists, at least in the vicinity of the coast, principally of red syenite and mica slate. Its interior is entirely unknown to geologists; but from its appearance as viewed from a distance, I infer that it consists of a number of elevated ridges similar to those of the Cobequid Mountains, and probably attaining an equal elevation. The patches of Lower Carboniferous rocks which appear at intervals along its margin, indicate that, like the Cobequids, it formed a rocky island in the seas of the Carboniferous period.*

We may now return to those portions of the rocks whose distribution has been sketched above, in which fossil remains indicative of their geological age have been found. The most important and instructive of these is *Arisaig*, in the county of Antigonish, a locality to which the writer first directed the attention of geologists in a paper published in the Journal of the Geological Society in 1848, and more fully in a paper published in the "Canadian Naturalist," vol. v.; and which has subsequently been more minutely described by Dr Honeyman.† For a knowledge of its fossils we are indebted principally to Professor Hall, who described forty new species from this place in con-

* See Appendix. † Journal of the Geological Society, 1864.

nexion with the paper above referred to in the "Canadian Naturalist," having examined all the specimens in my collection, with a considerable number of additional species kindly given to me by Dr Honeyman. Next to this is the locality on the east branch of the East River, referred to in the first edition of this work, and from which I have lately obtained additional collections made by Mr D. Fraser of Springhill. Another locality, to which attention was first directed by Dr Gesner, and Dr Webster of Kentville, is that of New Canaan, in King's County. I shall notice these in detail, and with them a few other places where similar fossils have been detected.

Arisaig.—Near this place, at the extreme northern limit of the Silurian system on the eastern coast of Nova Scotia, is one of the most instructive sections of these rocks in the province. At the eastern end of the section, where they are unconformably overlaid by Lower Carboniferous conglomerate and interstratified trap,* the Silurian rocks consist of gray and reddish sandy shales and coarse limestone bands dipping south at an angle of 44°. The direction of the coast is nearly east and west, and in proceeding to the eastward, the dip of the beds turns to south 30° west, dipping 45°, so that the series, though with some faults and flexures, is on the whole descending, and exhibits, in succession to the rocks just mentioned, gray and dark shales, with bands and lenticular patches of coarse limestone, some of which appear to consist principally of brachiopodous shells *in situ*, while others present a confused mass of drifted fossils. Below these the beds become more argillaceous, and in places have assumed a slaty structure, and occasionally a red colour. The thickness of the whole series to this point was estimated at 500 feet. The dip then returns to the south, and the beds run nearly in the strike of the shore for some distance, when they become discoloured and ochraceous, and then red and hardened; and finally, at Arisaig Pier, are changed into a coarse reddish banded jasper, where they come into contact with a great dike of augitic trap of Carboniferous date. Beyond this place they are much disturbed, and, so far as I could ascertain, destitute of fossils; but Dr Honeyman has detected fossils in their continuation at Doctor's Brook. The alteration of the beds extends to a distance of 300 yards from the trap, and beyond this in some places slaty cleavage and reddish colours have been produced; the latter change appearing to be connected with vertical fissures traversing the beds.

In the lower or shaly portion of the Arisaig series, the characteristic fossils are *Graptolithus* not distinguishable from *G. Clintonensis*, *Lepto-*

* See my paper on Eastern Nova Scotia, J. Geol. Soc., 1844. Section *ante*.

cœlia (*Atrypa*) *intermedia* (Hall), a new species closely allied to *L. hemispherica* of the Clinton group of New York, *Atrypa emacerata*, *Orthis testudinaria*, *Strophomena profunda*, *S. rugosa*, *Rhynchonella equiradiata*, *Avicula emacerata*, *Tentaculites*, allied to or identical with *T. distans*, *Helopora* allied to *H. fragilis*. There are also abundant joints and stems of crinoids, and a *Palæaster*, the only one as yet found in Nova Scotia, which was presented to me by Dr Honeyman, and has been described by Mr Billings in the "Canadian Naturalist" under the name of *P. parviusculus*. These and other fossils associated with them, in the opinion of Professor Hall, fix the Geological position of these rocks as that of the Clinton group, the Upper Llandovery of Murchison, in the central part of the Upper Silurian.

In the upper and more calcareous part of the series, fossils are very abundant, and include species of *Calymene*, *Dalmania*, *Homalonotus*, *Orthoceras*, *Murchisonia*, *Clidophorus*, *Tellinomya*, and several brachiopods, among which are *Discina tennuilamellata*, *Lingula oblonga*, *Rhynchonella quadricosta*, *R. Saffordi* (Hall), allied to *R. Wilsoni*, *R. neglecta*, *Atrypa reticularis*, all found in the Upper Silurian elsewhere in America. Most of the other forms are new species, descriptions of which have been given in Professor Hall's paper. The general assemblage is on the whole not unlike that of the Clinton, but is of such a character as to warrant the belief that we may have in these beds a series somewhat higher in position, and probably equivalent to the Lower Helderberg, the Ludlow of the English geologists. The new species *Chonetes Nova-Scotica* is very characteristic of the upper member.

On the whole, we must regard the Arisaig series as representing the middle and upper parts of the Upper Silurian, a position somewhat lower than that assigned to it in the first edition of "Acadian Geology." In explanation of this, I may further state that, in papers published previously to 1855, I had regarded these rocks as Silurian; and that it was only in deference to the opinions of able palæontologists, both in Britain and America, who compared the fossils with those of the Hamilton group, that I abandoned this view, returning to it in 1859, when enabled to do so by Professor Hall's examination of the fossils, the results of which were published in 1860. It is only just to Dr Honeyman to state, that he had independently stated similar conclusions in Nova Scotia in 1859. Unfortunately the Arisaig series stands alone, wedged between Carboniferous and Plutonic rocks, so that little opportunity occurs on the coast of verifying the conclusions derived from fossils, by the evidence of stratigraphical connexion with newer or older Silurian deposits, and I have been unable

to devote sufficient time to this object to attempt to trace the beds in their succession or continuation inland.

Dr Honeyman has addressed himself with some success to the work of tracing the relations and continuation of the beds exposed in the Arisaig section, and has published an interesting paper on the subject in the Journal of the Geological Society (1864). In this paper he divides the whole series seen at Arisaig into five sub-sections, noted respectively in ascending order as A, B, B′, C, D. He distinguishes the groups A and B from my *Lower* Arisaig series, which he regards as equivalent to his groups B′ and C, while D is the equivalent of my *Upper* Arisaig series.

Group A, of Dr Honeyman's paper, includes the altered jaspideous shales seen near Arisaig Pier, and the gray argillaceous and arenaceous shales of Doctor's Brook. Dr Honeyman mentions, as occurring in them, species of *Orthoceras*, *Murchisonia*, *Strophomena*, *Orthis*, *Rhynchonella*, *Calymene*, *Cornulites*, *Tentaculites*, and *Petraia* (?), and, on the authority of Mr Salter, regards them as equivalents of the English Mayhill sandstone, a member of the Upper Llandovery series. Their thickness is estimated at 200 feet.

Groups B and B′ include principally dark and ferruginous shales. One of the most characteristic fossils of which is *Graptolithus Clintonensis*. They contain also *Tentaculites*, joints of crinoids, *Strophomena depressa*, and other fossils; and Dr Honeyman has added in his paper two species of *Grammysia*, *G. triangulata*, and *G. cingulata*, and several other fossils not determined as to species. This group is regarded by Dr Honeyman and Mr Salter as equivalent to the Lower Ludlow of England, which is above the horizon of the American Clinton and Niagara.

Group C, which is also characterized by fossils in the main Clinton in character, is regarded by Dr Honeyman and Mr Salter as the equivalent of the subordinate group known in England as the Aymestry limestone. The beds of this group are harder than those of the last and more calcareous; and in addition to the fossils mentioned above as characteristic of the Lower Arisaig series, Dr Honeyman mentions *Rhynchonella Saffordi*, *Spirifer rugaecosta*, and some other fossils previously regarded by me as characteristic of the upper series, and which indicate that this group includes the transition from the lower to the upper member.

Group D, of Dr Honeyman's paper, is equivalent to my Upper Arisaig series, and contains a great number of fossils, some of which are of Lower Helderberg or Upper Ludlow types, and so strikingly resemble those figured by Sir R. Murchison in his "Siluria," as char-

acteristic of that group, that the most cursory glance would assure a geologist of their probable identity. Yet, as observed by Professor Hall, there is also a mixture of forms looking toward a much lower part of the Upper Silurian series; and it is worthy of notice that Hall, comparing the fossils with those of New York, gives to the upper members of the series a rather lower or older place than that assigned by Salter in comparison with English fossils, taking as our standard the equivalency of formations in England and America as usually recognised. As the species are in great part different from those of England and America, this slight difference of result may depend merely on defective data, and may be explained when larger materials have been collected, and when we shall be in a position to make allowance for the geographical as well as geological relations of the formations. On either view the equivalent of the Niagara or Wenlock series does not appear, and we may suppose it absent, or that an upward extension of Clinton forms occupies the Niagara period.

Merigomish.—Dr Honeyman has traced the fossiliferous Upper Silurian along the hilly country crossing the upper waters of the rivers of Merigomish, connecting the Arisaig rocks with those next to be noticed on the East River of Pictou. What may be the arrangement of the beds in this thick band of slaty rocks is not certainly known, but they appear to contain equivalents of the Upper Arisaig series and also beds with *Graptolithus Clintonensis*, and others containing nodules charged with *Lingulæ*. Below these are beds with *Petraia* (?) and *Cornulites*, which may be equivalents of the lowest group at Arisaig. On the north, these rocks are overlaid by the Carboniferous rocks of the coast. On the south, they are continuous, with a broad belt of metamorphic and igneous rocks, the former of similar mineral character, extending across the country to the valley of the St Mary's River. The only locality in which fossils have as yet been discovered in this broad belt is at Lochaber Lake, where Dr Honeyman has found some of the Arisaig fossils and also a species of *Zaphrentis*, a form which, with some other obscure fossils found at this place, would seem to indicate the presence of beds possibly newer than those of Arisaig. The occurrence of these fossils at Lochaber, as well as the mineral character of the beds, shows that a belt of country about fifteen miles in breadth is here occupied principally by Upper Silurian rocks, probably thrown into a series of synclinal and anticlinal folds, and penetrated by considerable masses and dikes of Syenitic and Dioritic rock.

East River of Pictou.—We next find the fossiliferous Upper Silurian rocks on the east branch of the East River of Pictou,

and its vicinity, where these deposits rise from beneath the Lower Carboniferous series, forming the high ground on the eastern side of the river. The beds are here much altered, and penetrated by igneous dikes, and are vertical, or with very high southerly dips and N.E. and S.W. strike. They consist of coarse slates and calcareous bands resembling those of the Upper Arisaig series in mineral character, and holding many of the same species, especially *Chonetes Nova-Scotica;* but we have here in addition a great bed of fossiliferous peroxide of iron, in some parts forty feet in thickness, and with oolitic structure; but passing into a ferruginous sandstone, and associated with slate and quartz rock. The precise age of these ferruginous rocks relatively to the Arisaig series, it is not easy to determine, but they are evidently Upper Silurian. The stratigraphical evidence, though obscure, would place them in the upper part of the series. The fossils are in a bad state of preservation; but, in so far as they give any information, it coincides with the apparent relation of the beds. Similar ferruginous beds occur in the Clinton series (the Surgent of Rogers) in New York and Canada; and as we have already seen in the Lower Devonian in the western part of Nova Scotia. On the whole, I regard the beds seen at the East River of Pictou as belonging to the same line of outcrop with the Arisaig series, but as probably containing, in addition to the upper member of that series, beds somewhat higher in position.

I am indebted to Mr D. Fraser of Springville, East River, for a large addition to my collection from this place; by the aid of which I am now enabled to present the following list, which has been kindly revised by Mr Billings. Unfortunately, many of the specimens were in a condition too imperfect to permit of satisfactory specific determination, and Mr Billings, with proper caution, declined to give them specific names for the present, in the hope that better materials might be found. The species common to the East River and Arisaig are indicated by an asterisk.

* *Chonetes Nova-Scotica*, Hall, very characteristic of certain hard calcareous bands.

C. tenuistriata, Hall.

Strophomena, flat striated species.

Spirifera, resembling *S. cycloptera*, but with regular ribs.

* *Spirifera rugaecosta*, Hall.

* *Spirifera subsulcata*, Hall.

Rhynchonella (?) n. s., like *R. transversa*, Hall. This and another species very abundant in hard impure limestone.

* *Atrypa reticularis.*
* *Crania* (?) *Acadiensis.*
Athyris (*Meristella*) *didyma*, a characteristic European Upper Silurian shell.
Lingula.
* *Megambonia striata.*
Megambonia (?) n. s.
Clidophorus (?) n. s.
Pterinea or *Megambonia.*
Orthonata or *Nuculites* (?) n. s.
* *Bucania trilobita*, Hall.
Murchisonia, two species.
Platyceras.
* *Orthoceras punctostriatum*, Hall. Some specimens found at East River, with the external markings of this species, are as much as two inches in diameter.
Orthoceras (?) n. s.
Cyrtoceras (?) n. s.
* *Cornulites flexuosa*, and probably another species.
Beyrichia, two or more species.
* *Calymene Blumenbachii.*
Serpulites.
* *Stenopora* allied to *S. fibrosa.*

Cobequid Mountains.—At the eastern end of this chain, in Earlton and New Annan, though the rocks are generally in a highly metamorphosed condition, fossils are found in a few places; and in so far as I have been able to determine from very small suites of specimens, are those of the Arisaig series. From the apparent continuity of strike along this long salient line of outcrop, it seems probable that these fossils indicate the true age of the greater part of the sedimentary rocks of the Cobequid Hills; a conclusion confirmed by their similarity in mineral character to the altered equivalents of the Arisaig and East River series as seen elsewhere. There are, however, some indications of beds of Devonian age, along the flanks of these hills, especially at their eastern end. The arrangement of the beds and their mineral contents, in the central part of the chain, will be found noticed in my paper of 1849, already referred to. They are not known to contain beds of iron ore; but have enormous vein-like deposits of spathic and specular iron associated with the carbonates of lime and magnesia, and running with the strike of the beds. These will be described in the section relating to useful minerals.

New Canaan.—Between the East River of Pictou and New Canaan, in King's County, 100 miles distant, I know no Silurian beds with fossils south of the Cobequid Hills; and in the central part of the province these rocks disappear under the Carboniferous deposits. In the hills of Horton and New Canaan they reappear, and constitute the northern margin of a broad belt of metamorphic and plutonic country, occupying here nearly the whole breadth of the peninsula. The oldest fossiliferous beds seen are the fine fawn-coloured and gray clay slates of Beech Hill, in which Dr Webster, many years since, found the beautiful *Dictyonema*, mentioned in a previous page. It is a new species, closely allied to *D. retiformis* and *D. gracilis* of Hall, and has received the name of *D. Websteri*, in honour of its discoverer. It is most readily characterized by the form of the cellules, which are very distinctly marked in the manner of *Graptolithus*. A portion of a frond is represented in Fig. 196.

The Dictyonema slates of Beech Hill are of great thickness, but have in their upper part some hard and coarse beds. They are succeeded to the south by a great series of dark coloured coarse slates, often micaceous, and in some places constituting a slate conglomerate, containing small fragments of older slates, and occasionally pebbles of a gray vesicular rock, apparently a trachyte. In some parts of this series there are bands of a coarse laminated magnesian and ferruginous limestone, containing fossils which, though much distorted, are in parts still distinguishable. They consist of joints of crinoids, casts of brachiopodous shells, trilobites and corals. Among the latter are two species of *Astrocerium*, not distinguishable from *A. pyriforme* and *venustum* of the Niagara group, and a *Heliolites* allied to *H. elegans*, if not a variety of this species. On the evidence of these fossils, and the more obscure remains associated with them, Professor Hall regards these beds as equivalents of the Niagara formation of the New York geologists, the Wenlock of Murchison. Their general strike is N.E. and S.W.; and to the southward, or in the probable direction of the dip, they are succeeded, about six miles from Beech Hill, by granite. They have in general a slaty structure coinciding with the strike but not with the dip of the beds, and this condition is very prevalent throughout this inland metamorphic district, where also the principal mineral veins usually run with the strike. The beds just described run with S.W. strike for a considerable distance, and are succeeded in ascending order by beds holding the fossils of the Upper Arisaig series, which are

either but slightly developed or obscured by imperfect exposures, and on these rest the Lower Devonian slates and iron ore of Nictaux, already described.

Regarding the above as the most typical and most thoroughly explored portions of the Upper Silurian of Nova Scotia, it is important to attain to as correct notions as possible as to their equivalency with the beds of that system elsewhere. In estimating this, we must bear in mind the fact that they belong to the Eastern or Atlantic slope of America, in which the Upper Silurian rocks are not only more altered by heat and chemical agents than in the great central plain west of the Alleghanies, but appear to have differed in the original character of the deposits. These would seem to have been more affected by local differences of deposition, so as to produce great diversities of mineral character within limited distances. They seem also on the whole to have been more argillaceous and less calcareous. These considerations may serve to account for the apparant absence of the great Niagara formation, the equivalent of the English Wenlock, from the Arisaig section, while the Clinton is greatly developed; and the Niagara formation, under a peculiar modification, occurs in considerable thickness at New Canaan and Kentville. Beyond the limits of Nova Scotia, the Upper Silurian of Southern New Brunswick and of the State of Maine presents much resemblance both in its mineral character and fossils to the Arisaig group in Nova Scotia. On the other hand, in Northern New Brunswick and Gaspé, beyond the great Lower Silurian belt of Northern New Brunswick, the Upper Silurian becomes more calcareous, and differs much in its fossils from the Upper Silurian of Nova Scotia. The Island of Anticosti presents another development of the lower part of the Upper Silurian not hitherto recognised in Nova Scotia.

In the presence of so great local diversity, it seems chimerical to compare our Upper Silurian either with the fine and regular series of New York and Upper Canada (Ontario) or with the English series. It must be admitted, however, that, in a general way, the Nova Scotia Upper Silurian presents in its fossils characters in some respects intermediate between the American and European series, and therefore comparable with either or both. As the general result of the facts already stated, in their bearing on these questions, I may state the following conclusions:—(1.) The Upper Arisaig and Nictaux series may be regarded as on the horizon of the Lower Helderberg of New York and the Ludlow of England, though with some older forms among their fossils. (2.) The New Canaan beds are probably

equivalent to the Niagara of New York and the Wenlock of England. (3.) The Lower Arisaig series represents the Clinton of New York, and the Upper Llandovery series of England, with perhaps a portion of the time elsewhere represented by the Wenlock or Niagara. (4.) It is not improbable that the fossiliferous rocks recognised by Dr Honeyman at Doctor's Brook may represent a somewhat lower member of the Upper Silurian, but still probably not so low as the Medina and Oneida of New York, or the Lower Llandovery of England. I entertain no doubt that farther and more minute investigation will make the details of our Nova Scotian and New Brunswick Upper Silurian more complete. I think, however, that the above general comparison will continue in the main to hold good. In my own limited researches, I have found much difficulty to arise from the want of identity of the fauna with that of typical Silurian localities, from the imperfect preservation and frequent distortion of the fossils, and from the difficulty of tracing the succession of the contorted and faulted beds. These difficulties can only be finally overcome by detailed surveys and extensive collection of specimens. In the meantime, much caution is necessary in writing on the subject.

2. *Upper Silurian of New Brunswick.*

I have coloured certain limited areas in Southern New Brunswick as Upper Silurian, on evidence which I think indisputable, collected principally by Mr Matthew and Professor Bailey, and detailed in a paper by the former in the Journal of the Geological Society, and in the Report of the latter on the Geology of Southern New Brunswick. From these sources the following statements are taken. These rocks constitute the "Kingston Group" of the last mentioned Report, from which I quote the following description:—

"The peninsula of Kingston, constituting the neck of land lying between the Long Reach and the Kennebeckasis in the county of King's, has heretofore been described as a region composed solely of eruptive rocks, such as trap, syenite, and greenstone, and in previous geological maps has been undistinguished from the widely different volcanic beds which occur in other portions of the province. In reality this group of rocks is quite distinct, and is of very uniform as well as remarkable characters.

"To describe the district as wholly a volcanic one is essentially erroneous. Although beds of such an origin are abundant, and taken collectively occupy much space, they are seldom purely eruptive, being invariably associated with aqueous deposits, and being themselves for

the most part of a stratified metamorphic character. The whole peninsula is of sedimentary origin, and in some portions, aqueous deposits have alone been concerned in its formation. Although occupying an extensive area, little variety is apparent, the group consisting principally of compact felspathic rocks, with some chloritic slates and numerous beds of interstratified greenstone or diorite.

"Three parallel bands, differing slightly in character, and running the entire length of the peninsula, may be distinguished.

"The first, forming the southern side of the peninsula, and skirting the north shore of the Kennebeckasis in a series of very bold and remarkably picturesque cliffs, is largely schistose, and extends with an almost unbroken front from the Milkish to Hampton Ferry. Near the latter place and opposite Darling's Island, the group is represented by the following rocks:—

"Gray gneiss (?) or altered micaceous sandstone, with small crystals of red felspar.—Str. N. 60° E.

"Greenstone or diorite.

"Porphyritic felspathic schist of a pink colour, weathering white.

"Gray felspathic quartzite, injected with quartz veins.

"Grayish white altered slate.

"The whole series is nearly vertical, and no satisfactory dip could be ascertained. My impression is that the tendency is to the north.

"In the neighbourhood of Clifton, rocks of the same band contain large masses of chlorite and epidote, with veins of specular iron.

"The second band of rocks alluded to, although passing insensibly into the last, differs from it chiefly in the much greater abundance of altered sandstones and bedded greenstones, with a comparative infrequency of slaty beds. The greenstones or diorites are interstratified with compact felspathic rocks, varying from white to pale pink, the latter at times associated with and passing into fine-grained syenite and syenitic gneiss. Slates are comparatively rare, and when occurring, are sometimes chloritic and sometimes micaceous, being also, as a rule, much twisted. Like the members of the first division, these rocks also contain chlorite and epidote. The group may be readily seen in the village of Kingston, or along the Land's End at the southwest extremity of the peninsula.

"The third band, into which the last insensibly passes by the absence of its bedded diorites, occupies principally the northern side of the peninsula, where it is represented by a comparatively uniform series of clay and chloritic slates. Though not so numerous as in the centre and south of the district, trap beds are present, and at times

rise into bold ridges. This is especially the case near the middle of the Reach, where they produce some interesting scenery.

"The rocks of the Kingston group, besides occupying the peninsula which properly bears that name, extend to the eastward within the limits represented on the map. Like most of the older formations in this part of the province, they are progressively covered to the eastward by Carboniferous rocks. They extend, however, on the south as far as Dickie Mountain, near Norton Station, and upon the north within a few miles of Belleisle Point, forming two bands, separated by a valley now occupied by Carboniferous sandstones and limestones.

"On the northern shore of the Long Reach, lying between the main river and the granites of the Nerepis, is a band of rocks which I have, with some doubt, referred to the group now under consideration. I have not been able to examine this district in sufficient detail to fully establish its relative age, but have connected it with the Kingston rocks, for the following reasons:—

"*1st.* At the extremity of Oak Point, towards the head of the Reach, and in the rocky islands occurring in this neighbourhood, the beds are undoubtedly connected with those of Kingston. At Oak Point two varieties occur, interstratified with each other.

"(*a.*) Very hard, black and green bedded diorite, with calc spar, chlorite, and epidote.

"(*b.*) Light-coloured fine-grained felspathic rocks, graduating into coarser beds of syenite and syenitic gneiss. (General strike, N. 50° E, Dip N ?). These latter are undoubtedly altered sandstones and conglomerates.

"*2d.* Rocks similar to the above seem to form a well defined band extending westward as far as the Nerepis. At Jones' Creek they are well exposed in thick beds, and apparently rest on a still thicker series of blue and gray altered slates. These latter are little disturbed, having a strike about east and west, and a southerly dip of 62°.

"Along the line of the Nerepis, and in the neighbourhood of the Douglas Arms, altered rocks similar to the above in their granitoid aspect occur, and are probably a continuation of the same series.

"Between these and the great granite range of the Nerepis valley, altered sandstones and slates, diorite, felsite, and cherty quartzite, occur.

"It will thus be seen that the band of rocks now under consideration resembles those of Kingston, in the presence of felspathic and greenstone beds, while it differs principally in the abundance of coarse

syenite, and syenitic gneiss. The rocks of Oak Point seem to be a connecting link between the two.

"To the southwestward of the series last described, and directly opposite the termination of the Kingston peninsula, the nature and relations of the rocks are no longer doubtful. The abundance of pale pink felsites and felspathic quartzites, with beds of interstratified greenstone, at once recalls the rocks of Kingston, and indicates an extension of this series to the westward. Except along the line of the main river, however, their development in this direction is little known, the district being as yet wholly unsettled. Rocks probably forming a part of the same series appear far to the south-west, along the New River, in the County of Charlotte. (See the Geological Map.)

"While the rocks of Kingston have thus been shown to occupy an extensive district, west and north of the St John River, along both shores of the Reach, observations in other localities would seem to indicate a corresponding easterly extension.

"It has already been stated that, while occupying the entire peninsula from which their name has been derived, these rocks may be traced to the eastward in two diverging ridges, the one terminating at Dickie Mountain, near Norton Station, the other at a short distance below the head of Belleisle Bay. Stretching along the northern side of the latter, and forming the watershed between the tributaries of the Belleisle and Washademoak Rivers, is a ridge of rocks, somewhat variable in composition and of moderate elevation, which, though exhibiting some peculiarities, can with difficulty be distinguished from the deposits of Kingston and the Reach."

In Professor Bailey's Report these rocks are described in detail, as they occur at Bull Moose Hill, Belleisle Corner, and Kars. The following remarks may be made with reference to their age and stratigraphical relations:—

(1.) A series of specimens were submitted by Professor Bailey to the author and Dr Hunt, with the results stated in the following words:—

"In regard to the probable age of these rocks, Dr Hunt does not regard them as very like anything he knows in Canada. They are not like the Quebec group or the Laurentian, our two principal series of metamorphic rocks in Lower Canada.

"In comparing them with Nova Scotia, I have no hesitation in saying that they are *unlike* our Atlantic coast series, which I believe to be Lower Silurian, but that they are very like the rocks of the Cobequid Mountains and of the inland hills of Eastern Nova Scotia, which I believe to be Middle and Upper Silurian. This is the age to

which I would therefore be inclined to refer your rocks, though I would not affirm that they may not include Lower Devonian, which in Nova Scotia are altered with the Upper Silurian.

"I regard your specimens as altered sediments, though some of the felspathic and hornblendic ones may be true Plutonic rocks."

(2.) Mr Matthew has found, in loose fragments, near St John, probably derived from these rocks, the following fossils:—*Chonetes*, *Pterinea* or *Avicula*, *Clidophorus*, *Orthis*, *Rhynchonella* (?), *Leptodomus* (?), etc.; and still more recently specimens have been obtained from undoubted members of the Kingston group, in which the following characteristic Upper Silurian assemblage of genera occurs, though in a state too imperfect for specific determination.

The genera are *Dalmania*, *Phacops*, *Orthoceras* (2 species), *Murchisonia* (2 species), *Loxonema*, *Holopea* (?), *Lucina* (?) or *Anatina* (?), *Avicula* (?), *Leptodomus* (?), *Spirifer*, *Chonetes* (?), *Atrypa*, *Rhynchonella* (?), *Retzia* (?), *Strophomena*, *Orthis*, *Discina*, *Favosites*, *Zaphrentis* (2 species), *Syringopora* (?), and other corals. From Frye's Island also, in the south-western extension of these rocks, Upper Silurian fossils have been obtained.

(3.) A comparison of these rocks with those in Maine, in their line of strike, and ascertained by Hitchcock to be Upper Silurian, confirms the above evidence from mineral character and fossils.

One source of perplexity in the determination of these rocks arises from the fact that, in the vicinity of St John, the Devonian rests on the Lower Silurian without the intervention of Upper Silurian beds. This, as Mr Matthew suggests, may be accounted for by denudation, or by the elevation of the Lower series before the deposition of the Upper. In Maine, however, it would seem that these rocks appear in their regular sequence below the Devonian.

It will be observed that, as in Nova Scotia, the Upper Silurian sediments are more argillaceous and less calcareous than the beds of this age in the more inland parts of the continent, and that they are also much more metamorphosed. In both of these particulars we shall find a decided difference in the Upper Silurian of *Northern* New Brunswick, next to be noticed.

A glance at the map will enable the reader to perceive, extending south-west from Bathurst, in the Bay de Chaleur, that broad and rugged belt of altered Lower Silurian and Plutonic rocks, the terror of railway engineers, which forms the natural limit of Acadia on the north-west, and separates the Coal-field of New Brunswick from the Upper Silurian valley of the Restigouche and Upper St John, the debateable land, in point of physical geography, between the high lands of

the Nepisiguit which belong to New Brunswick, and the high lands of Rimouski and Gaspé which belong to the Province of Quebec.

This belt of very ancient rocks was probably a physical barrier even as early as the Upper Silurian period; for on passing it we find in the valleys of the Restigouche and the neighbouring streams beds of highly calcareous and fossiliferous Upper Silurian rock identical in character with those of Gaspé, and differing both in mineral character and the assemblage of fossils from those which we have just been studying. The southern limit of this Upper Silurian area, in so far as it is known, may be seen on the map; and its structure may be learned from the following description by Professor Hind of the section at Cape Bon Ami, near Dalhousie. The section is in ascending order, and the dips are to the northward at an angle of 45°.

1. Trap.

2. Calcareous shales.

3. Trap or trappean ash, more or less stratified, and with veins of carbonate of lime and quartz.

4. Calcareous shales and honestones, weathering buff or pale yellow.

5. Trap, vesicular, hard and black, weathering red.

6. Calcareous shale and limestone, with honestone. Many layers are fissile and shaly, weathering buff, others are hard and silicious. The limestones contain *Favosites Gothlandica*, *Strophomena rhomboidalis*, etc. In the upper part of this series there appears to be a conglomerate 14 feet thick, capped by honestone 36 feet thick.

7. Massive trap.

8. Limestone highly fossiliferous. Among its fossils are *Favosites Gothlandica*, *F. polymorpha*, *F. basaltica*, *Strophomena rhomboidalis*, *S. punctulifera*, *Calymene Blumenbachii*, *Atrypa reticularis*.

9. Trap, highly ferruginous.*

It is instructive to observe the large amount of bedded trap or volcanic ash in the above section. This accords with the presence of large quantities of apparently interstratified igneous rock in the Kingston group and in the Cobequid Mountains, as already noticed. Such interstratified volcanic matters are abundant in some parts of the Silurian of Great Britain. They are comparatively rare in other parts of Nova Scotia, though beds of this kind occur in New Canaan. Similar traps occur in Gaspé, but they are absent from the typical Upper Silurian of New York and Western Canada. Their presence indicates the recurrence of volcanic eruptions at frequent intervals during the Upper Silurian period.

A collection of fossils from the beds at Dalhousie and its vicinity

* The total thickness of the above series is not stated by Professor Hind.

has been kindly communicated to me by Professor Bailey, and has been submitted to Mr Billings, who regards the species as equivalent to those of the Port Daniel limestones of the northern side of the Bay de Chaleur, which may be regarded as intermediate in age between the Niagara and Lower Helderberg groups, and therefore probably not far from the horizon of the Upper Arisaig series, or perhaps between this and the Lower Arisaig group.

The following fossils from Dalhousie and Restigouche, now in the Museum of the University of New Brunswick, have been determined by Mr Billings. The assemblage is in the main that of the Lower Helderberg.

Favosites basaltica.
Favosites Gothlandica.
Zaphrentis, n. s., same as one in the Gaspé limestone.
Stenopora.
Halysites catenulatus.
Syringopora.
Diphyphyllum.
Orthis tubulistriata, Hall, or allied.
Orthis oblata, Hall.
Strophomena rhomboidalis.
Strophomena punctifera, Conrad.
Strophomena varistriata.
Spirifera cycloptera.
Atrypa reticularis.
Cyrtia Dalmani.
Rhynchonella vellicata, Hall.
Athyris princeps, or allied.
Leptocœlia, allied to L. hemispherica.
Fenestella.
Megambonia, allied to M. ovoides, Hall.
Conocardium.
Pleurotomara, allied to P. labrosa, Hall.
Euomphalus sinuatus (?)
Dalmanites.

General Remarks.

The group of partially metamorphic Upper Silurian rocks above described includes the most elevated land of Nova Scotia and Southern New Brunswick. The Cobequid range, attaining at several points a height of 1200 feet, is the highest chain of hills in Nova Scotia; and forms, in its whole length, the watershed dividing the streams flowing

into Northumberland Strait and Chiegnecto Bay from those flowing into Cobequid Bay and Mines Basin and Channel. In like manner, the complicated group of hills extending westward from Cape Porcupine and Cape St George, though less elevated than the Cobequid hills, contains the sources of all the principal rivers of the counties through which it extends. The largest of these is the St Mary's river. Its western branch, originating in the same elevated ground that gives rise to the Musquodoboit, the Stewiacke, and the Middle River of Pictou, flows for about thirty miles nearly due east along the valley which here separates the Lower and Upper Silurian districts. Its east branch flowing from the hills in the rear of Merigomish, and passing near the lakes from which the principal branch of the East River of Pictou flows, receives tributary streams from the metamorphic promontory stretching towards Cape Porcupine, and unites with the west branch at the northern margin of the Lower Silurian metamorphic band. The united stream then flows through a narrow valley, cutting the Lower Silurian belt transversely, to the Atlantic.

Judging from the direction of the principal streams, as for instance the Liverpool River, it would appear that in the western counties, as well as in the eastern, this group of metamorphic rocks, with its associated igneous masses, forms the most elevated ridges. In the southern part of New Brunswick also, and in Cape Breton, we everywhere find these rocks forming rocky ridges separating the river valleys.

The character of the surface over these rocks is very similar to that which prevails in those parts of Lower Canada (Quebec) and New England, in which similarly altered Upper Silurian rocks occur. The soil, where not too rocky for cultivation, is fertile; and in their natural state the hills are clothed with a rich growth of hard-wood trees.

M. Jules Marcou, in the summary of American geology which accompanies his geological map, endeavours to apply to these elevations De Beaumont's theory of the parallelism of mountain ranges of like age. According to this view, the Cobequid Mountains, and the hills on the east side of the Bras d'Or Lake, belong to a system of elevations older than the Lower Silurian rocks; and the Merigomish and Antigonish Mountains, with the hills of Western Cape Breton, to a later dislocation, dating at the close of the Silurian period. It appears to me that both these dates are by much too ancient. I have already stated that the rocks of the Cobequid Mountains have been altered and elevated before the Carboniferous period; but, on the other hand, these altered rocks themselves are in

part Devonian, and there is no reason to believe any of them to be older than Upper Silurian. I would therefore refer the great line of dislocation of the Cobequids, which runs nearly W. 10° S., as well as the nearly parallel lines of the south mountains of King's County, the range ending in Cape Porcupine, and most of the hills of Cape Breton, to the close of the Devonian period. These ranges have, however, been broken and deranged in places, as at the eastern end of the Cobequids, the Antigonish Mountains, the hills near Guysboro', and in the south-west of Cape Breton, by disturbances probably coeval with the great Alleghany range, that is, at or toward the end of the Carboniferous system, and there is evidence that between this time and the end of the Devonian period, igneous action was constantly more or less felt, and was also accompanied by elevatory movements. Hence these later movements in part, as along the Cobequid range, have conformed to the course of the older movement, and in part have broken out into irregular projecting ridges, having a tendency to a north-east and south-west direction. In short, the study of these elevations in Nova Scotia tends to show, that though there may be a certain parallelism between elevatory movements of the same period, when they take place in districts previously undisturbed, yet that in regions broken up by previous dislocations, they may either conform in direction to these, or break forth irregularly from them along lines of least resistance produced by previous transverse fractures. It is to be observed, however, that those very marked and important physical changes which closed the Devonian period were preluded by volcanic outbursts extending through the Upper Silurian and Devonian eras.

In New Brunswick, the area occupied by the Kingston group is broken and elevated, and separates what may be termed the southern bay of the Carboniferous area from the remainder. As an ancient geographical feature, it is also connected with the large development of Lower Carboniferous rocks in this bay or arm. Still, it is not sufficiently extensive or continuous to give it any great importance in the present drainage of the country. The great Upper Silurian area in Northern New Brunswick is of much more importance in this respect, and contains the principal sources of the St John and the Restigouche; the former of which, the largest river of Acadia, gathering the waters of many tributaries from a great area chiefly of Upper Silurian rocks, finds a devious path through transverse valleys of the great Lower Silurian belt, crosses the south-west angle of the Carboniferous area, and entering the Silurian band of the coast, follows its strike for some distance in the "Long Reach" before it finds its way to the sea.

Before leaving these rocks, I must state that their boundaries, as marked on the map, are often very rude approximations to the truth. It is impossible in the present state of our knowledge to distinguish accurately between these older rocks and the Carboniferous beds which have in many parts of their borders been metamorphosed with them, or to indicate accurately the position and limits of the irregular masses and dikes of igneous rocks. An immense amount of labour will be required before these disturbed and altered rocks can be accurately mapped, or their intricacies fully unravelled.

Useful Minerals of the Upper Silurian in Nova Scotia.

Iron, in veins traversing the altered rocks, abounds in this district; and it also occurs in thick beds coeval with the neighbouring slates, and filled, like them, with fossil-shells. I shall first notice those deposits which are *veins* properly so called. These, though occurring in many places, have been worked only along the southern slope of the Cobequid Hills in Londonderry, in the vicinity of the Great Village and Folly Rivers. This deposit appears to have been noticed as early as the time when the land on which it occurs was granted by the Crown; and it received some attention from Mr Duncan and other gentlemen in Truro nearly twenty years ago. No steps were, however, taken toward its scientific exploration until 1845. In the summer of that year I received a specimen of the ore for examination, and in October of the same year I visited and reported on the deposit. In the same autumn it was examined by Dr Gesner. In 1846 I again visited it, and reported on it to C. D. Archibald, Esq., of London, and other gentlemen associated with him; and in the summer of 1849 I had the pleasure of again going over the ground and examining the vein at some new points, in company with J. L. Hayes, Esq., of Portsmouth, U. S. Since 1849 the extent and economical capabilities of the deposit have been discussed by several writers, both in this province and in Great Britain; and it has been opened, and smelting furnaces erected by an association of capitalists.

I shall begin by describing the vein as it occurs on the west branch of the Great Village River, at the site chosen by C. D. Archibald, Esq., for the furnace and buildings of the "Acadia Mine," and as seen in 1849. In the western bank of this stream, at the junction of the Carboniferous and Metamorphic series, a thick series of gray and brown sandstones and shales of the former system, dipping to the south at angles of 65° and 70°, meet black and olive slates, having a nearly vertical position, and with a strike N. 55° E. The dip of these slates, where apparent, is to the southward, and the strike of the slaty

cleavage and of the bedding appears to coincide. Near the falls of the river, a short distance northward of the junction just noticed, the slates give place to gray quartzite, which, with some beds of olive slate, occupies the river-section to, and for some distance beyond, the iron vein.

The vein is well seen in the bed of the stream, and also in excavations in the western bank, which rises abruptly to the height of 327 feet above the river-bed. In the bottom of the stream it presents the appearance of a complicated network of fissures, penetrating the quartzite and slate, and filled with a crystalline compound of the carbonates of lime, iron, and magnesia, which, from its composition and external characters, I refer to the species *Ankerite*. With this mineral there is a smaller quantity of red ochrey iron ore, and of micaceous specular iron ore.

In ascending the western bank of the stream, the vein appears to increase in width and in the quantity of the ores of iron. In one place, where a trench was cut across it, its breadth was 120 feet. Though its walls are very irregular, it has a distinct underlie to the south, apparently coinciding with the dip of the containing rocks. As might have been anticipated from its appearance in the river-bed, it presents the aspect of a wide and very irregular vein, including large angular fragments of quartzite, and of an olivaceous slate with glistening surfaces. These fragments are especially large and abundant in the central part of the vein, where they form a large irregular and interrupted rocky partition.

That the reader may be enabled to understand the description of this singular deposit, I give the composition of the various substances contained in it, as ascertained by my own analyses and examinations.

1. *Specular Iron Ore*, or nearly pure peroxide of iron, in black crystalline scales and masses.

2. *Magnetic Iron Ore*, a compound of the peroxide and protoxide of iron. This and the first-mentioned ore, as they occur intermixed in this vein, are capable of affording from 60 to 70 per cent. of pure iron. Both of these ores have been introduced into the vein by igneous fusion or sublimation.

3. *Ochrey Red Iron Ore*. This is the most abundant ore in the vein, and is of great value on account of its richness and easy fusibility. It is also the material of which the mineral-paint produced by this region is manufactured. It varies somewhat in quality, but the purest specimens are peroxide of iron, with scarcely any foreign matter.

4. *Ankerite*, or carbonate of iron, lime and magnesia. This is the most abundant material in the vein, and is usually of a grayish-white colour, though sometimes tinged red by the peroxide of iron. A

specimen of the reddish variety, containing small scattered crystals of specular iron, gave on analysis—

Peroxide of iron . . .	33·0
Carbonate of lime . . .	46·0
Carbonate of iron . . .	19·5
Carbonate of magnesia . .	·8
Silicious sand	·4
	99·7

The white variety consists of—

Carbonate of lime . . .	54·
Carbonate of iron . . .	23·2
Carbonate of magnesia . .	22·
Silicious sand	·5
	99·7

With this mineral is found a variety of *Spathose Iron*, or sparry carbonate of iron, containing about 20 per cent. of carbonate of magnesia. It is of a light yellow colour, and runs in little veins through the Ankerite. I have no doubt that all these substances have been molten by heat, and injected from beneath into the irregular fissure in which they are now found. The ochrey red ore, previously mentioned, appears to be a result of the subsequent action of heat on the spathose iron. The ankerite and spathose iron may become valuable for mixing with the other ores, affording lime for a flux and much iron.

5. *Yellow Ochrey Iron Ore.* This is found in great quantity on the surface of the vein, and has resulted from the rusting of the ankerite, which soon becomes covered with a yellow rusty coat when exposed. The yellow ochre is a peroxide of iron combined with water, and when calcined it affords a good red pigment. On analysis, it gave—

Peroxide of iron . . .	74·52
Alumina	4·48
Carbonate of lime and magnesia	·40
Silica and silicates . .	6·20
Water, mostly combined .	14·40
	100·00

6. *Brown Hematite* occurs in large balls along the outcrop of the vein. It has been produced by the solvent action of acid water on the carbonate of iron, and the subsequent precipitation of iron from these solutions. It is a valuable ore, but is probably most abundant near the surface of the vein.

7. *Sulphate of Barytes* occurs in small crystals lining fissures, and in compact veins in the ankerite. Though quite insoluble, this substance can be decomposed by heated solutions of alkaline carbonates; and when these are cooled it is re-formed and deposited.* It has probably been introduced in this way into this vein.

I shall endeavour in the following remarks to state the manner in which these minerals occur in the complicated mixture which fills this vein, and their probable origin. Let the reader then imagine that he is standing on the side of the deep ravine of the Great Village River, looking into a rocky excavation in which the minerals above mentioned appear to be mixed together in the most inextricable confusion, in great irregular cracks of the slaty rocks, and he will be able, perhaps, to wade through the following description.

The ankerite should evidently be considered the veinstone, as it surrounds and includes all the other contents of the vein, and greatly exceeds them in quantity. Where not exposed, it is white and coarsely crystalline. On exposure it becomes yellowish; and near the surface, as well as on the sides of fissures, it is decomposed, leaving a residue of yellow ochrey hydrous peroxide of iron. In some parts of the vein, the ankerite is intimately mixed with crystals and veinlets of yellowish spathose iron. The red ochrey iron ore occurs in minor veins and irregular masses dispersed in the ankerite. Some of these veins are two yards in thickness; and the shapeless masses are often of much larger dimensions. Specular iron ore also occurs in small irregular veins, and in disseminated crystals and nests. At one part of the bank there appears to be a considerable mass of magnetic iron ore, mixed with specular ore; this mass was not, however, uncovered till after I had left the ground.

The whole aspect of the vein, as it appears in the excavations in the river-bank, is extremely irregular and complicated. This arises not only from the broken character of the walls, the included rocky fragments, and the confused intermixture of the materials of the vein; but also from the occurrence of numerous transverse fissures, which appear to have slightly shifted the vein, and whose surfaces usually display the appearance named "slickenside," and are often coated with comminuted slate or iron ore. In some places these are so numerous as to give an appearance of transverse stratification. One of them was observed to be filled with flesh-coloured sulphate of barytes, forming a little subordinate vein about an inch in thickness.

The general course of the vein, deduced from observations made by Mr Hayes and myself at the Acadia Mine and further to the eastward,

* Bischoff, quoted by De la Beche. Geol. Obs. p. 669.

is S. 98° W. magnetic, the variation being 21° west. At the Acadia Mine this course deviates about 33° from that of the containing rocks. In other localities, however, the deviation is much smaller; and in general there is an approach to parallelism between the course of the vein and that of the rock formation of the hills, as well as that of the junction of the Carboniferous and Metamorphic systems. The vein, for a space of seven miles along the hills, is always found at distances of from 300 yards to one-third of a mile northward of the last Carboniferous beds, and always in the same band of slate and quartzite.

Westward of the Acadia Mine the course of the vein over the high ground is marked by the colour of the soil, as far as Cook's Brook, about a mile distant. The outcrop of the ore was not exposed in this brook, but large fragments of specular ore have been found in its bed, and a shaft, sunk on the course of the vein, has penetrated more than forty feet through yellow ochre containing a few rounded masses and irregular layers of ankerite. At this point the decomposition of the ankerite and spathic iron has extended to a much greater depth than usual, and is so perfect that a specimen of the yellow ochre was found to contain only ·4 per cent. of the carbonates of lime and magnesia; the remainder being hydrous peroxide of iron, alumina, and silicious matter.

Still further west, in Martin Brook, I observed indications of the continuation of the vein. Beyond this place I have not traced it; but I have received specimens of specular iron ore and ankerite from the continuation of the same metamorphic district, as far west as the Five Islands, twenty miles distant from Acadia Mine.

On the east side of the west branch of the Great Village River, the ground does not rise so rapidly as on the western bank, and the vein is not so well exposed. On this side, however, a small quantity of copper pyrites has been found in or near the vein, but it does not seem to be of any importance. Indications of the vein can be seen on the surface as far as the east branch of the river. In the east branch, red and gray conglomerates, dipping to the south, and forming the base of the Carboniferous system, are seen to rest unconformably on olive, black, and brown slates, whose strike is S. 75° W. The continuation of the iron vein was not observed in the bed of this stream.

Further eastward, on the high ground between the Great Village and Folly Rivers, indications of the ores of iron have been observed; especially near the latter river, where in two places small excavations have exposed specular and red ores, and where numerous fragments of brown hematite are found scattered on the surface.

The ravine of the Folly River affords a good natural section of the

quartzite and slate of the hills, as well as of the Carboniferous beds of the lower ground. This section, as far as the base of the hills, is described in Chapter XV. The lowest Carboniferous bed is a thick, coarse, gray and brownish conglomerate, dipping S. 20° W. It rests unconformably on a bed of slate very similar to that seen in a like position at the Great Village River, and which differs considerably in appearance from most of the slates of these hills. The strike of the slate is S. 70° W.; and that of the bedding and slaty structure appear to correspond. In a layer of graywacke included in this slate I observed small and well-rounded pebbles of light-coloured quartz. This slate is succeeded by thick beds of gray quartzite and hard olivaceous slates. These occupy the river section for about 700 yards, or as far as the "Falls," where the river is thrown over a ridge of quartzite fifty-five feet in height; a small rill pouring in on the eastern side from a much greater elevation. Between the conglomerate and the waterfall the quartzite contains a few narrow strings of ankerite, and at the fall there is a group of reticulating veins, some of them six inches in thickness. They contain a little iron pyrites. These are the only indications of the iron vein observed in this section; and as the group of beds in which it should occur is well exposed, it is probable that it is represented here only by these small veinlets distributed over a great breadth of rock. Above the fall the quartzite and slate continue to alternate for a considerable distance, the dip being generally to the southward, in one place at as low an angle as 55°. About a quarter of a mile above the fall they are traversed by a dike or mass of fine-grained hornblendic igneous rock.

On the elevated ground east of the Folly River the vein is again largely developed, and two excavations exposed a part of its thickness on the property of the Londonderry Mining Company. The excavation nearest to the river showed a thickness of 190 feet of rock on the south side of the vein. This consists of gray quartzite, olive slate, and about three feet of black slate. These beds are traversed by a few small strings of ankerite, which increase in dimensions on approaching the broken and irregular wall of the vein. About seventeen feet of the south side of the vein consist principally of ankerite. Adjoining this on the north is red iron ore, with nests of specular ore, veins and blocks of ankerite decomposed in part to yellow ochre, and fragments of rock. Ten feet in thickness of this red ore were seen without exposing the north wall of the vein.

On the surface in this vicinity are large fragments of brown hematite, which mark the course of the vein. In the eastern excavation, this mineral was seen in place near the surface and occupying fissures

in a fragment of quartzite. In this second excavation the red ore was more largely mixed with the micaceous specular variety, and also included large rounded blocks of ankerite and angular fragments of rock. The width exposed here was thirteen feet, and neither wall was seen. The ankerite is decomposed to the depth of eight feet. The same appearance of transverse vertical layers seen at the Acadia Mine is observed here, and is probably due to the same cause.

Still further east, on the property of C. D. Archibald, Esq., and on ground equally elevated, three excavations have shown a still greater development of the vein. A trench fifty-three feet in length, and nearly at right angles to the course of the vein, showed in its whole length a mixture of red and specular ores with ankerite. Another excavation, ninety-five feet to the northward of the first, exhibited ankerite tinged of a deep red colour by peroxide of iron, and traversed by reticulating veins of red iron ore. A third opening, 365 feet south-eastward of the first, showed white and gray ankerite, having some of its fissures coated with tabular crystals of white sulphate of barytes. The walls of the vein were not seen at this place; but 150 paces south of the first trench a thick dike of greenish igneous rock, apparently a very fine-grained greenstone, appears, with a course of S. 102° W. This dike was not seen westward of this place, but it can be traced for a considerable distance to the eastward. In the Mill Brook, two miles east of Folly River, it appears in connexion with a bed of black slate near the margin of the metamorphic system, and probably a continuation of that seen in a similar position in the Folly and Great Village Rivers. At the Mill Brook the dike is about 100 feet in thickness.

In the bed of the Mill Brook, the vein is seen in the form of a network of fissures chiefly filled with ankerite; and in its eastern bank it attains a great thickness. In the bank of another brook still further to the eastward, and in the same line of bearing, it appears to be of large dimensions, and contains abundance of red iron ore and red ankerite. I have not traced it further to the east, but I have no doubt of its continuance to a great distance in that direction.

The geological history of this deposit embraces the following occurrences:—*1st*, The formation of a wide irregular fissure, along a great part of the length of the Cobequid Mountains. *2dly*, The filling of this fissure with a molten or softened, and partially even sublimed, mass of ferruginous and calcareous matter, presenting, as I think, an evident illustration of the igneous formation of a vein of calcareous, magnesian, and ferruginous carbonates. *3dly*, The breaking up of the vein thus formed by cross-fractures and faults. *4thly*, The partial roasting of its contents by heat, so as to produce the red ores, which

are obviously the result of the heating and oxidation of a part of the carbonate of iron, and this process may be seen, on minutely examining the vein, to have extended itself from the walls of the smallest fissures. *5thly*, The action of heated waters passing through its crevices, and depositing sulphate of barytes and brown hematite. *6thly*, The influence of the air and surface waters in changing large portions of the superficial contents of the vein into ochrey hydrous peroxide of iron.

It is, however, to be observed that this deposit might be accounted for on the supposition that a bed of iron ore and carbonate of lime and magnesia, similar to those occurring elsewhere in the Upper Silurian, had been so softened and altered by heat as to penetrate in vein-like forms the surrounding rocks. Sir W. E. Logan has shown that phenomena of this kind occur in the Laurentian regions of Canada.

This deposit is evidently wedge-shaped, being largest and richest on the surface of the highest ridges. It contains, however, an immense quantity of valuable ores of iron, though its irregular character opposes many difficulties to the miner. Difficulties have also been found in smelting the ore to advantage; but these are often incident to the first trials of new deposits, to which the methods applicable to others, of which the workmen have had previous experience, do not apply. It is believed, however, that these preliminary hindrances have been overcome, and that the mine has now become highly profitable to its proprietors. I quote the following estimate of the value of the deposit from the elaborate Report of J. L. Hayes in 1849. It has been fully confirmed by experience:—

"From the descriptions which I have above given, it is evident, that although the unlimited extent of the ore at any particular point can only be determined by working the deposits, yet an immense field is open for explorations and working.

"Although it is quite probable that an abundant supply of ore will be found upon the west bank of the river, at a price which will not exceed two dollars to the ton of iron; if this should not be the case, an ample supply can be furnished from the other localities at an expense which, including raising and hauling, could not exceed four dollars to the ton of iron. I would advise the opening of the veins at different points upon the line, to determine the cheapest point for mining, and the ores which can be used most advantageously. If this is done, the price of the ore cannot be fairly set down at the sum for which it can be obtained from the nearest locality, but at an average of the prices of the ores from different localities, delivered at the point selected for the furnace. This may be estimated at three dollars to the ton of iron.

"The value of this locality with respect to ore may be judged of by comparing it with establishments in the United States. In Berkshire County, Massachusetts, at some establishments which have been successfully conducted, the price of the ore is between five and six dollars to the ton of iron. In Orange County, New York, ore yielding between 40 and 50 per cent. costs between four and five dollars to the ton of iron. At one locality in New York the ore costs ten dollars to the ton of iron. At some establishments on Lake Champlain, ore costing one dollar per ton at the mine, is carried twelve miles to the furnace. The ore at the Baltimore furnaces costs over seven dollars to the ton of iron. This is about the average cost of the ore at the furnaces in Pennsylvania. Estimating the cost of the ore even at four dollars to the ton of iron, there will be advantage over the average American localities.

"The cost of ores at some of the Swedish and Russian furnaces is still greater. In certain parts of the Ural Mountains the minerals are carried by land to the forests a distance of from 40 to 80 miles. Some of the forges of Sweden are supplied with minerals from Presburg and Dannemora, which are transported by land-carriage, the lakes, and the sea, to distances exceeding 370 miles.

"There is no trace of sulphur, arsenic, or any foreign matter which can deteriorate the quality of the iron, or of titanium or chrome, which would render the ores refractory. The red ochrey ore, the most abundant variety, being sufficiently porous to present large surfaces to the reducing gases in the blast furnace, and yet sufficiently compact not to choke the furnace, but to allow the free passage of the blast, can be used with peculiar advantage. The daily make of iron from these ores will be large, and the consumption of combustible comparatively small.

"I have no doubt that iron of the first quality for purity and strength, and which will demand the highest prices in the market, can be made from these ores. If Mr Mushet's opinion, based upon his own experiments, that these ores will furnish steel-iron equal to the best Swedish marks, should prove correct, these ores possess a rare value; for, of the many charcoal iron establishments in the United States, I know but one which furnishes iron suitable for making the first quality of steel."

In addition to the use of the ores of iron in these deposits as sources of the metal, *mineral paints* and *artificial slate* of excellent quality are manufactured from the iron ochres of the Folly Mountain, and are extensively used for protecting wooden buildings, etc.

Since the publication of the first edition of this work, extensive

mining and smelting operations have been carried on at the Londonderry mines, and in 1865 I saw a thriving mining village where, in 1849, there had been but a wild wooded ravine. I had not time to visit the excavations; but Dr Honeyman informs me that the original vein at Great Village still holds out, or rather appears as two veins, about twenty feet apart, and each with from four to five feet of ore, though occasionally widening to about twenty feet or diminishing to mere strings. One of them consists chiefly of brown hematite. Extensive openings have been made at Martin's Brook, where the ore is also hematite. The ore is now smelted with charcoal, large quantities of which are made in the neighbouring hills; but a great extension of the operations is anticipated, so soon as the railway shall connect the mines with the coal district of Springhill. The reputation of the iron made from this ore is very high, owing to its excellent quality, and suitableness to the manufacture of steel.

Within the last few years veins of hematite are stated to have been discovered in rocks of Upper Silurian age on the East River of Pictou, near Springville, and I have received from a locality near the French River of Merigomish a fine specimen of compact carbonate of iron, which is said to occur there in large quantity, though whether as a vein or bed I am not informed.

Veins of iron ores, similar in character to those above described, occur in nearly every part of this metamorphic district; they are, however, of small magnitude, and I am not aware that they are in any place of workable dimensions. In many places extensive masses of shattered quartzite and slate are penetrated in every direction by slender veins of micaceous specular iron ore.

In addition to these *veins* of iron ore, conformable beds, as already mentioned, exist in the Upper Silurian slates, more especially on the East River of Pictou, at the locality indicated on the map. At this place, one bed appears to be forty feet thick, and much resembles that in the Devonian at Nictaux, but the ore is more silicious, and contains only about forty per cent. of metal. It is not at present worked. This bed of ore could no doubt be traced extensively, and must eventually become of great economical importance. Though the ores are less rich than those of the Cobequid Mountains, the deposits are likely to be more continuous and persistent. This great bed of ore on the East River of Pictou is especially worthy of the attention of capitalists engaged or about to engage in smelting operations, as it is only ten miles distant from the Albion coal-mines, and is in the vicinity of abundance of limestone and

building-stone. The hematite and clay ironstone of the same region might also be profitably used with the specular ore of the great bed.

Copper ores occur in several parts of this district. In the country eastward of the Lochaber Lake, in the county of Sydney, large fragments of copper and iron pyrites are found in the surface gravel, and have no doubt been derived from a vein containing this ore, along with ores of iron similar to those of the Cobequid Hills, and which are found attached to the loose fragments. These indications were examined by the author in 1848, and made known to the Mining Association. A Cornish miner was afterwards employed by the Association to explore the locality, but his labours were unsuccessful; and as yet nothing has been found except the loose masses already referred to, some of which are from two to three feet in diameter. The strike of the rocks at this place is S. 70° W. to S. 20° W., and the district in which the ores occur consists of olive, gray, and black slates, with beds of quartzite and dikes of greenstone and compact felspar. In some places the slates are filled with small veinlets of specular iron ore and ankerite. The pyrites contains from four to seventeen per cent. of copper, the average of several specimens being 10·8 per cent. This would be a valuable ore if found in sufficient quantity and of easy access; there appear, however, to be serious difficulties in the way of opening the deposit, more especially its low situation and the depth of the surface cover.

Copper pyrites, yielding 31·6 per cent. of copper, and therefore of very rich quality, has been found on the south branch of Salmon River; but I am not aware that it occurs in sufficient quantity for mining purposes. This ore has also been found in small quantity near the Acadia iron-mine, and in the barytes veins at the Five Islands.

Sulphate of Barytes.—This mineral occurs in considerable quantity, in numerous irregular veins traversing the slates in the banks of the East River of the Five Islands. I have little doubt that these veins are strictly a continuation of the great iron veins already described; but here barytes predominates, and only a small quantity of specular iron is present and a very little copper pyrites. The barytes at this place is pure white, and often in very beautiful crystalline masses. Its cavities are coated with fine crystals of carbonate of lime of the variety known as dog-tooth spar. Large quantities of barytes have been extracted at this place, by levels and open excavations in the steep sides of the ravine, and have been exported to the United States; but I believe the demand has not been found sufficient to warrant a

continuance of the works on a large scale. The presence of copper ores at this place, associated with such a veinstone as sulphate of barytes, affords some promise that if the excavations were continued, valuable quantities of such ores would be discovered.

White marble occurs in the metamorphic slates at Five Islands, as well as a coloured marble of a purplish hue, with green spots tinged by serpentine. These beds at Five Islands have not been sufficiently opened fairly to test their quality. The white marble affords small specimens of great purity and of very fine grain. The coloured variety has been objected to on the ground of unequal hardness.

Slate, apparently of good quality, is found in New Canaan, and on the Middle River of Pictou. It is not at present quarried, but the first-mentioned locality would appear to present great facilities for profitable working.

Syenite and *Porphyry*, suitable for building and ornamental purposes, occur in various parts of the Cobequid Mountains, and on the east side of the Bras d'Or, and other places in Cape Breton. Owing to their inland position, and the want of any internal demand, these rocks are not at present quarried.

Smoky Quartz, in large and beautiful crystals, is found in the surface debris at Paradise in Annapolis County; and its native matrix is a reddish compact felspar, which occurs in veins in the granite of that district.

Useful Minerals of the Upper Silurian in New Brunswick.

The Upper Silurian rocks of Charlotte County afford promising indications of lead and copper, and are a continuation of the metalliferous rocks of Washington County, Maine; but little has yet been done to ascertain their actual value. To this age are referred the copper ores of Le Tete and the sulphate of barytes of Frye's Island, said to be in large quantity and accessible. Copper and iron have been stated to occur at Dickie Mountain and Bull Moose Hill, in the Kingston group; but are not very favourably reported on by Professor Bailey. As I have not personally examined any of the localities, I may refer the reader for such information as is at present to be obtained to the Reports of Professor Bailey and Professor Hind.

It may be anticipated that the igneous and metamorphic hills of this district in Nova Scotia and New Brunswick, so varied in their composition, and at present so little open to detailed investigation, will be found to contain many useful minerals in addition to those

above mentioned; and that as population and enterprise increase, they will become important mining and manufacturing districts.

The soils of this district are in general good. They produce in their natural state a fine growth of hardwood timber, sufficient for a long time to supply the demands of the shipyards and iron furnaces, and when cultivated they are remarkably favourable to the growth of hay and grain crops. They are well supplied with lime and phosphates; and when deep are less easily exhausted than most other kinds of upland. Hence in the more fertile parts of these hills, as in Southern Horton, Earlton, New Annan, the Pictou Hills, Lochaber, and Northern Cape Breton, there are fine and flourishing agricultural settlements, which, in spite of a climate a little more rigorous, are advancing more rapidly in wealth than most of the lower districts.

Fossils of the Upper Silurian.

Under this head I give the descriptions of new species published by Professor Hall in 1860, and notices of additional species since obtained, including the *Palæaster* described by Mr Billings, and species mentioned by Mr Salter as occurring among Dr Honeyman's specimens submitted to him, also the specimens communicated to me by Professor Bailey in 1867.

1. *Radiata.*

Stenopora, allied to *S. fibrosa*. East River, Arisaig.

Favosites Gothlandica, Lin. Dalhousie, Professor Bailey.

Favosites polymorpha, Goldfuss. Dalhousie, Professor Bailey.

Favosites basaltica, Goldfuss. Dalhousie, Professor Bailey.

Helopora fragilis, Hall, var. Acadiensis. Arisaig, coll. J. W. D.

Zaphrentis, n. s., identical, according to Mr Billings, with a species from Port Daniel. Dalhousie, Professor Bailey.

Astrocerium pyriforme, Hall. New Canaan, coll. J. W. D.

Astrocericum venustum, Hall. New Canaan, coll. J. W. D.

Heliolites, allied to *H. elegans*. New Canaan, coll. J. W. D.

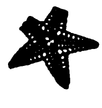
Petraia Forresteri, Honeyman, Arisaig. I have seen no description or figure of this species.

Dictyonema Websteri, Dawson. Beech Hill (for description and figure see p. 163, *supra*).

Palæaster parviusculus, Billings (Fig. 197). The specimen is about six lines in diameter. The rays are two lines in length and one line and a half in width at the base, tapering at an angle of a little less than 45°. The five oral plates are sub-pentagonal, about half a line in width. The first adambulacral plates of each pair of

adjacent rays are in contact with each other outside of the oral plates, and not completely separated as they are in *P. Niagarensis*. There are six or seven adambulacral plates on each side of the ambulacral groove in each ray, and they gradually decrease in size from the oral plate outwards to the point of the ray. The width of the ambulacral groove is equal to one-third the width of the ray, and consequently the adambulacral rows of plates are also each equal to one-third the whole width of the ray. In each groove there are two rows of small and apparently nearly square ambulacral plates, twelve or fourteen in each row, and they seem to be continued round on the inner margin of the oral plates; the mouth is about one line wide.

Fig. 197.
Palaeaster parviusculus.



This species differs from *P. Niagarensis*, Hall (Pal. N. Y., Vol. 2, page 247, Pl. 51, Figs. 21, 22, 23), in being smaller, the rays not so slender, and more importantly in the junction of the adambulacral plates outside of the oral plates.

The specimen was collected at Arisaig by Rev. Dr Honeyman.

2. *Mollusca.*

Crania Acadiensis, Hall (Fig. 198). Circular or broadly sub-oval, moderately convex, the greatest convexity near the apex; apex obtuse.

Several casts show a central elevated area, with strong muscular impressions; the more elevated portion being surrounded by a flattened border, which is radiatingly striate.

These specimens are casts which appear to be of the ventral valve; and the form of the muscular impressions is so characteristic of the genus that I can have little hesitation in thus referring them. Arisaig, East River, coll. J. W. D.*

Discina tenuilamellata, var. *subplana*. Shell broadly elliptical, or suborbicular, externally depressed, apex subcentral; surface marked by thin sharply elevated lamellæ.

This closely resembles the Niagara species of New York, but may be distinct. Should further examination prove it a distinct species, the name *D. subplana* may be adopted. Arisaig, coll. J. W. D. Three other species of *Discina* are mentioned by Dr Honeyman as in his Arisaig collections.

Chonetes Nova Scotica, Hall (Fig. 199). Shell semi-elliptical, width varying from once and a half to nearly twice the length. The

* Of the species from Arisaig thus marked, some specimens were collected by Dr Honeyman, and were placed with my own collections in the hands of Professor Hall.

ventral valve variably convex, and often showing a flattened or slightly concave space down the middle of the shell; cardinal margin ornamented by four or five minute spines on each side of the beak; cardino-lateral margins often a little wrinkled; surface finely striated, striæ flexuous, dichotomising and increasing by interstitial addition, so that there are more than 100 on the margin of the shell; striæ increasing in size below the umbo; concentric striæ fine, close, rounded and slightly undulating.

Fig. 198.
Crania Acadiensis.

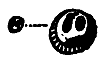


Fig. 199.
Chonetes Nova Scotica, and portions magnified.

Fig. 200.
Chonetes tenuistriata.

Fig. 201.
Trematospira Acadiæ.

Fig. 202.
Leptocœlia intermedia.

Dorsal valve moderately concave; striæ much stronger below the middle of the shell and sometimes bifurcating toward the margin.

This species resembles in form the *Chonetes cornuta* of the Clinton group of New York, but is a much larger and more ventricose shell; the striæ are proportionally less numerous and more closely arranged, the interstices being less than the striæ, while in the *C. cornuta* the interstices are wider than the striæ, and the latter increase only by interstitial additions below the middle of the shell. A stronger and more elevated stria often marks the median line from beak to base of the ventral valve. Arisaig, East River, Nictaux, coll. J. W. D.

Chonetes tenuistriata, Hall (Fig. 200). Shell semi-oval, twice as wide as long; ventral valve moderately convex, hinge-line equalling the width of the shell; surface marked by fine, even, closely arranged striæ, which apparently increase only by interstitial additions, and are not flexuous. The number of striæ on the margin of the shell is nearly 100.

This species is more finely striated than the preceding, the striæ not flexuous, more even, and in shells of equal size much more numerous. This species is sowewhat larger and more closely striated than the *C. cornuta* of the Clinton group of New York. Arisaig, East River, coll. J. W. D.

Spirifer rugæcosta, Hall. Shell somewhat semi-elliptical; dorsal valve very convex, with the mesial fold depressed along the centre; ventral valve with a wide deep mesial sinus; plications six or seven

on each side of the mesial fold and sinus, strong, and much elevated, subangular, crossed by numerous strongly elevated, lamellose, imbricating concentric striæ.

The specimens examined are almost all imperfect casts, some of which preserve the impression of the strong concentric striæ, and in one or two specimens an impression of the shell reveals the strength of the surface markings.

In many respects this species resembles the *S. perlamellosa* of the Lower Helderberg group in New York, but the mesial elevation of this species is flattened or depressed, a character never observed in New York specimens. Arisaig, East River, coll. J. W. D.

Spirifer subsulcatus, Hall. Shell semi-elliptical, hinge-line equalling or greater than the length of the shell below; plications five or six on each side of the mesial fold; mesial fold somewhat flattened or very slightly rounded on the summit; plications rounded; surface concentrically lamellose.

The specimens are all casts, or impressions of the shells.

They bear some resemblance to *S. sulcatus* of the Niagara group, and are intermediate between that species and the *S. cycloptera* of the Lower Helderberg group. Arisaig, East River, coll. J. W. D.

Spirifera, resembling *S. cycloptera*, but with regular ribs. East River, coll. J. W. D.

Strophomena profunda, Hall. Arisaig, coll. J. W. D. Dalhousie, Professor Bailey.

S. rugosa. Arisaig.

S. flat striated species. East River, coll. J. W. D.

S. corrugata, Conrad. Arisaig, coll. J. W. D.

Tremastospira Acadiæ, Hall (Fig. 201). Shell wider than long; beak of the ventral valve produced and incurved; mesial depression marked by a small fold on each side, which originates about one-third of the length below the beak and continues to the margin; sinus bounded on each side by a more strongly elevated plication, beyond which are six other plications on each side. Surface marked by fine concentric striæ.

This shell is referred to the genus *Trematospira* from external characters alone, which are unlike *Rhynchonella* proper, and the shell is not a *Spirifer*. Arisaig, coll. J. W. D.

Rhynchospira sinuata, n. sp. Shell ovoid, ventricose beak of the ventral valve incurved; a mesial sinus beginning a little below the beak; surface marked by about eight or nine simple scarcely subangular plications on each side of the mesial sinus.

Surface marked by concentric lines of growth.

This species differs from the *R. formosa* of the Lower Helderberg rocks of New York in the plications being more slender, in the more defined sinus of the ventral valve, and the continuation of the two small folds in the sinus nearly to the beak. Arisaig, coll. J. W. D.

Rhynchonella Saffordi. Shell varying in form from ovoid to globose. Full grown specimens usually wider than long, and sometimes becoming extremely ventricose, so that the diameter across the two valves much exceeds the length. Ventral valve depressed convex, with the beak minute, closely incurved; dorsal valve very ventricose, most prominent toward the front. Cardinal slope a little depressed, sides rounded, and the front in direct line flattened but not depressed. Surface finely plicated, plications little elevated, rounded or scarcely subangular, about five or six depressed in the flattened sinus of the ventral valve, and a corresponding number raised on the flattened mesial elevation, which rises abruptly, though usually but slightly above the lateral portions of the shell. From ten to fourteen plications mark the surface on each side of the mesial fold and sinus. Plications in front marked by a sharp groove along the centre, and those of each valve deeply interlocking.

This species resembles the *R. nucleolata* of the Lower Helderberg rocks of New York, and in some specimens it approaches to *R. ventricosa*, but is always much more finely plicated than either. It closely resembles the *R. Wilsoni* of Europe in its general form, but the plications are more rounded and somewhat coarser, and while in that species the sinus causes no depression in the ventral valve below the general surface of the shell, in ours there is an abrupt depression as well as a slightly abrupt elevation on the dorsal valve, while there is no similar feature in the *R. Wilsoni.**

The Nova Scotia specimens are in all respects identical with those from Tennessee. Arisaig, Earlton, coll. J. W. D.

The geological position of the specimen from Tennessee is in rocks of the age of the Lower Helderberg group, associated with *Pentamerus galeatus*, *P. Verneuili*, *Spirifer macropleura*, *Spirifer perlamellosa*, *Spirifer cycloptera*, and others.

Rhynchonella equiradiata, Hall. Arisaig, coll. J. W. D.

Rhynchonella neglecta, Hall. Arisaig, coll. J. W. D.

Rhynchonella, n. s. (?) allied to *R. transversa.* Arisaig, coll. J. W. D.

Leptocelia intermedia, Hall (Fig. 202). Shell concavo-convex; outline semi-elliptical, cardinal extremities rounded, and the hinge-line a little shorter than the greatest width of the shell; ventral

* Sowerby, M. C., vol. ii., page 38, says: The "sinus at the front, although deep, does not alter the evenness of the surface."

valve moderately convex, carinate in the middle by a strong plication with six or seven smaller ones on each side, the lateral ones slightly curved towards the outer extremity. Dorsal valve concave, with a broad shallow mesial sinus, the margins on either side being bent a little upward, giving a sinuous outline to the margin of the shell; surface marked by fine concentric striæ.

This species resembles the *L. hemispherica* of the Clinton group in New York in general form, but the hinge-line is shorter, and the extremities rounded; the mesial elevation consists of a single strong plication, while in *L. hemispherica* the surface is regularly plicated, with the central one sometimes a little stronger than the others. Arisaig, coll. J. W. D.

Atrypa reticularis, Dalman, Arisaig. East River, coll. J. W. D.

Atrypa emacerata, Hall. Arisaig, coll. J. W. D.

Athyris (*Merista*) *didyma*, Dalman. East River, coll. J. W. D.

Orthis testudinaria, Dalman. Arisaig, coll. J. W. D.

Lingula oblonga, Hall. Arisaig, coll. J. W. D.

Lingula, (?) n. s. Merigomish, Dr Honeyman.

Modiolopsis (?) *rhomboidea*, Hall (Fig. 203). Shell sub-rhomboid, rounded in front, wider and obliquely truncate behind, hinge-line slightly ascending from the anterior end; beaks subterminal, posterior umbonial slope obtusely subangular below, anterior to which the shell is flattened; basal margin nearly straight, the shell gradually widening behind, and the posterior basal extremity abruptly rounded. Surface evenly striated concentrically.

Anterior muscular impression very strong, posterior muscular impression less strongly defined, but still very conspicuous and subduplicate; palleal line simple, nearly parallel to the basal margin, strongly and almost equally defined in all parts of its length between the two muscular imprints.

This shell bears some resemblance to *M. primigenius*, but is less ventricose in the middle, and the sub-angular umbonial slope is not so well defined in that species. Arisaig, coll. J. W. D.

Modiolopsis sub-nasutus, Hall. Shell elongate sub-spatulate, the length being more than twice the greatest width at the hinge-line; slightly ascending posteriorly; beaks sub-anterior, the anterior end very narrow, gibbous on the umbones, with a sub-angular ridge on the umbonial slope which extends to the postero-basal angle; basal margin nearly straight, the posterior end somewhat flattened and obliquely sub-truncate at the extremity; surface marked by concentric lines of growth.

This shell bears a close general resemblance to *M. nasutus* of

the Trenton limestone, but a careful comparison shows it to be wider and more abrupt at its posterior termination, while the direction of the striæ of growth is very distinctive, these marks being regularly curving toward the posterior end in *M. nasutus*, while in this species they are abruptly bent at the postero-basal angle, and again on the cardinal side, corresponding with the truncate posterior extremity of the shell. Arisaig, coll. J. W. D.

Modiolopsis allied to *M. subcarinatus*. Arisaig, coll. J. W. D.

Clidophorus cuneatus, Hall. Shell ovoid, gibbous in the middle and on the umbones, gradually declining behind; beaks anterior, sub-terminal; anterior end broadly rounded, the posterior end narrower and sub-acute, posterior umbonial slope marked by an obtuse rounded ridge, which extends to the posterior extremity, and below this an undefined sinus which, expanding, extends to the postero-basal extremity, while a less defined ridge bounds this sinuosity on its anterior side; surface marked by fine irregular concentric striæ.

In the casts of this shell there is a strong linear straight clavicle, extending from a point just anterior to the beak two-thirds across the valve. Arisaig.

Fig. 203.
Modiolopsis rhomboidea.

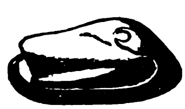
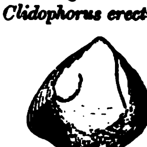


Fig. 204.
Clidophorus concentricus.

Fig. 205.
Clidophorus erectus.



Clidophorus concentricus, n. s. (Fig. 204). Shell sub-equilateral, very broadly oval-ovate, the anterior end the broader; height nearly four-fifths the greatest length; anterior side a little shorter and more broadly rounded at the extremity; a slight depressed sinus on the posterior umbonial slope, which is more anterior than in the preceding species. Surface marked by even band-like concentric striæ; shell thin; a linear curving clavicle extends from the cardinal line just anterior to the beak more than half way to the base.

The prominent points of distinction between this and the preceding shell are the nearly central beaks, the band-like striæ, and the curving clavicle with the broad and nearly equal extremities of the valve. Arisaig.

Clidophorus erectus, n. s. (Fig. 205). Shell somewhat rhomboid-ovate, the height and length about equal; umbones prominent, beaks nearer the anterior end, somewhat curved and elevated; posterior

cardinal line curving, with a scarcely defined ridge along the umbonial slope; basal margin strongly rounded, sinuate on the postero-basal margin and regularly rounded, with a scarcely defined ridge extending down the slope just anterior to the clavicle. Surface finely striated concentrically, a slightly curving clavicle extending from the cardinal line nearly two-thirds the distance to the anterior basal margin.

This species differs from the preceding in the equal length and breadth, and consequent greater proportional height, in the sinuosity of the postero-basal margin, and more abruptly-rounded basal outline, and the curving forward of the beaks. Arisaig.

Clidophorus elongatus, Hall (Fig. 206). Shell sub-elliptical, length about twice the height, beaks much nearer to the anterior end, which is narrowly rounded; umbones rounded, prominent; a defined gradually widening depression extends from the umbo to the posterior basal margin, causing a straightening or slight sinuosity in the edge of the shell; a defined ridge along the posterior slope between the sinus and the cardinal margin. Surface very finely striated. A slender clavicle extends from the anterior cardinal margin a little more than half-way to the base, and curving slightly forward.

Fig. 206. *C. elongatus.*

This species differs externally from all the others in the greater proportional length and in the rounded umbones.

The *C. cuneatus* of the same size is a stronger and proportionally higher shell, having a less defined sinus on the posterior slope, and a much stronger clavicle. Arisaig, coll. J. W. D.

Clidophorus semi-radiatus, Hall. Shell somewhat oval-ovate, length about one-third greater than the height.

Surface marked by fine concentric band-like striæ, and the posterior slope by flattened dichotomized radiating striæ, the two sets of striæ gradually dying out at their junction. A faint line anterior to the beak marks the place of the clavicle. Arisaig, coll. J. W. D.

Clidophorus nuculiformis, Hall. Shell nearly equilateral, subventricose, height and length as seven to nine. Anterior end rounded, basal margin regularly curved; posterior end sub-acute, a slight flattening or depression along the posterior umbonial slope, and between this and the cardinal line a narrow ridge. On the anterior slope there is a depressed line almost parallel to the cardinal line, marking apparently the course of the clavicle. Surface marked by fine concentric striæ.

This species resembles in form the *C. concentricus* in its equilateral form, but the fine unequal concentric striæ and the difference in direction of the clavicle are sufficient to distinguish it. Arisaig, coll. J. W. D.

Clidophorus subovatus, Hall. Shell, broadly oval or ovate, moderately and evenly convex; beaks near the anterior end; umbones moderately elevated; a scarcely defined depression extending from the umbo towards the postero-basal extremity; anterior extremity rounded, posterior extremity unknown (? regularly rounded); clavicle extending half way from the anterior cardinal margin to the base of the shell. Surface marked by fine unequal sub-lamellose striæ.

This shell is larger and more regularly convex than any of the others here described, and more inequilateral than any except the *C. cuneatus*. Arisaig, coll. J. W. D.

Nuculites (*Orthonota*) *carinata*, Hall (Fig. 207). Shell extremely elongate, nearly three times as long as wide; sides sub-parallel; hinge-line straight, beaks appressed, sub-anterior, the anterior extremity rounded; posterior extremity obliquely truncate, longer on the hinge-line than on the basal margin. Surface marked by a sharp carina which extends from the umbo obliquely to the postero-basal angle; the space anterior to this carina marked by distinct elevated lamellose striæ, and intermediate finer ones. The space between this and the cardinal line smooth and slightly depressed. Cardinal line anterior to the beak showing six or seven crenulations. A strong clavicle extends from the anterior cardinal line with a gentle curve nearly to the base of the shell. Arisaig, coll. J. W. D.

Fig. 207.
Nuculites carinata.

Fig. 208.
Tellinomya attenuata.

Fig. 209.
Megambonia cancellata.

This shell presents characters not before observed combined in one species. It has the general form of *Orthonta*, while the crenulated cardinal line and the anterior clavicle are characters of *Nuculites*. The shell is readily distinguished from species of either genus heretofore described. The Orthonotæ, yet known, have the surface marking much less sharply defined.

Tellinomya attenuata, Hall (Fig. 208). Shell elongate, narrow, more than twice as long as high, anterior end short and rounded; beak elevated, situated a little in advance of anterior third, posterior end narrow and abruptly rounded; basal margin slightly curved, and impressed posterior to the centre; posterior cardinal line straight but gradually declining; contour evenly convex. Surface concentrically striated, shell thick.

This shell resembles the *T. machæriformis*, but the anterior end is proportionally longer and more regularly round, the posterior narrower and more attenuated, and the convexity of the shell much greater. It is much smaller and proportionally more elongated than the *T. nasuta* of the Trenton limestone. Arisaig, coll. J. W. D.

Tellinomya angustata, Hall. Shell elongate, narrow elliptical, more than twice as long as wide, beaks fully one-third from the anterior end. The anterior and posterior ends similar and equally rounded; basal margin regularly curved without indentation or sinuosity. Surface evenly convex and very finely concentrically striated. Arisaig, coll. J. W. D.

Leptodomus (*Sanguinolites*) *aratus*, Hall. Shell rhomboid-ovate, ventricose, beaks at the anterior third of the valve, incurved and pointed forward, umbones gibbous, a slight depression from the umbo directly to the base of the shell, leaving a slight impression in the central margin; posterior slope sub-angular, the angle not defined; anterior slope with a defined angular ridge which borders a large cordiform lunette; anterior sharply rounded; basal margin nearly parallel with the hinge-line, curving upwards at the posterior extremity, and somewhat obliquely truncated from the cardinal line. Cardinal line straight posteriorly, with a wide and deep ligamental area. Surface marked by strong unequal ridges and furrows parallel to the basal margin, which become obsolescent on the posterior cardinal slope.

It is scarcely possible to refer any fossil with satisfaction to the genera *Sanguinolites* or *Leptodomus* of M'Coy, since the grouping of species under these names appears to us to comprise a heterogeneous assemblage in either case. Our shell corresponds in its external features with *Leptodomus costellatus* of M'Coy, so far as the general form, surface markings, ligamental area, etc., and is doubtless generically identical with that shell. Arisaig, coll. J. W. D.

Megambonia (?) *cancellata*, Hall (Fig. 209). Shell sub-ovate, widening posteriorly; beak anterior, incurved, umbo gibbous, with a gibbous umbonial slope on the posterior side, which is scarcely diverging from the cardinal line; posterior extremity rounded, the basal margin arcuate, with a slight impression anterior to the middle, the anterior end a little gibbous. Surface cancellated by concentric and radiating elevated striæ.

It is not possible from the specimen before me to refer the species satisfactorily to any known genus. Arisaig, coll. J. W. D.

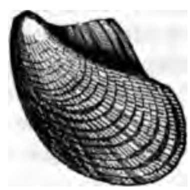
Megambonia striata, Hall. Shell somewhat oval, the basal and cardinal lines nearly parallel; beak sub-anterior, small; umbones

convex, scarcely gibbous; umbonial slope regularly convex, below which is a slight depression reaching to the postero-basal margin; posterior end rounded, the longer part of the curve on the basal side. Anterior end short and narrow, somewhat abruptly rounded. Surface marked by regularly radiating rounded striæ with faint concentric lines of growth.

This differs from the preceding species in being less gibbous, in the more nearly parallel cardinal and basal lines in the direction of the umbonial ridge, and in the stronger radiating striæ. Arisaig, East River, coll. J. W. D.

Avicula Honeymani, Hall (Fig. 210). Left valve: body of the shell obliquely ovate, convex and somewhat gibbous towards the umbo, anterior wing small rounded, posterior wing large triangular, obtuse at the extremity, extending two-thirds the length of the shell. The line between the wing and body of the shell well defined by a

Fig. 210.—*Avicula Honeymani.*



slight abrupt depression along the junction. Surface marked by rounded radiating striæ which are interrupted by fainter concentric undulations or lines of growth; the wing is marked only by concentric striæ.

This species bears some resemblance to *A. emacerata* of the Niagara and Clinton groups of New York; but its form is slightly more oblique, and the wing is marked only by concentric striæ, while in the New York species the radiating lines on this part are stronger than the concentric ones. Arisaig, coll. J. W. D.

Grammysia triangulata, Salter. Arisaig, Dr Honeyman.

Grammysia cingulata, Hisinger. Arisaig, Dr Honeyman.

Pterinea retroflexa. Arisaig, Dr Honeyman.

Goniophora cymbaeformis, Sow. Arisaig, Dr Honeyman. This and the three last shells I give on the authority of Dr Honeyman and Mr Salter.

Theca Forbesii, Sharpe. Collected by Dr Honeyman at Arisaig.

Murchisonia Arisaigensis, Hall. Shell teretely conical, volutions about five, gradually increasing from the apex, rounded with a slight angulation or carina in the middle. The surface is unknown, and the

angular band on the volution is the only means of determining its generic relations.

This differs from any of the described species of Murchisonia from American localities. Arisaig, coll. J. W. D.

Murchisonia aciculata, Hall. Shell slender, very gradually tapering, volutions about six or seven, the last ones moderately ventricose, aperture elongate-oval or ovate, rounded at the anterior margin, columella plain; volutions marked by a distinct band along the centre, and a sub-sutural carina marking the upper side of the volutions; surface striated. Arisaig, coll. J. W. D.

Pleurotomaria. A flat species with four turns. Arisaig, Dr Honeyman. Nictaux, J. W. D.

Holopea reversa, Hall (Fig. 211). Shell small, sinistral; spire depressed, volutions about three; the two first small and gradually expanding, the last one rapidly expanding and ventricose; aperture wide expanded; suture impressed. Surface unknown. This shell has the general form of Holopea, but I have seen only a single specimen, which is a cast. It is remarkable and readily recognised from the sinistral spire. Arisaig, coll. J. W. D.

Fig. 211.

Bucania trilobita, Hall. Arisaig, East River, Nictaux, coll. J. W. D.

Bellerophon expansus (?), Sow. Arisaig, Dr Honeyman.

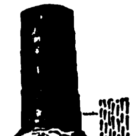
Bellerophon carinatus, Sow. Arisaig, Dr Honeyman.

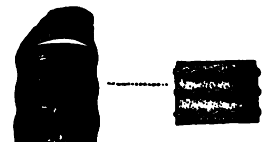
Platyschisma helicites, Sow. Arisaig, Dr Honeyman.

Acroculia helicites, Sow. Arisaig, Dr Honeyman. This and the three last species are from the lists of Dr Honeyman and Mr Salter.

Orthoceras punctostriatum, Hall (Fig. 212). Shell slender, very gradually tapering, almost cylindrical. Septa distant about one-third the diameter. Siphuncle central; section circular. Surface very finely striated with unequal undulating striæ, the interstices between which are punctæ, which are oblong indentations often becoming confluent.

Fig. 212. *Orthoceras punctostriatum*. Fig. 213. *O. elegantulum, and portion magnified.*





This species is remarkable for its extremely gently tapering form; the fragment of more than an inch long, showing scarcely a perceptible diminution in diameter. There are twelve and a half cham-

bers in the space of one inch. The surface markings are peculiar, and among the species of the genus known to us constitute a distinctive character. Large specimens nearly two inches in diameter from East River have the characters of this species. Arisaig, coll. J. W. D.

Orthoceras elegantulum, Dawson (Fig. 213). This is a very beautiful species, apparently new, but closely resembling *O. perelegans*, Salter, of the Lower Ludlow formation. It is cylindrical, but slightly flattened; septa very convex and one-twentieth of an inch apart in a specimen half an inch in diameter; siphuncle central. Surface with slight rounded annulations from one-eighth to one-fourth of an inch apart, and covered with delicate transverse striæ, scarcely visible to the naked eye, and about sixteen in a line. Under the microscope the striæ appear as thin sharp parallel curved ridges, the spaces between being finely granulated and wider than the ridges. Arisaig, coll. J. W. D.

Orthoceras (?), n. s. East River, coll. J. W. D.

Orthoceras (?), n. s. Nictaux, coll. J. W. D.

Cyrtoceras, n. s. East River, coll. J. W. D.

Orthoceras exornatum, Dawson. Arisaig, coll. J. W. D. This species, collected by Dr Honeyman at Arisaig, is circular in the cross section, moderately tapering, and straight; with the siphuncle slightly excentric, and septa half a line to a line apart, in a specimen two to four lines in diameter. The surface is slightly annulated, and ornamented with about twenty-four flat longitudinal flutings in the manner of a Doric column. The whole surface is also delicately striated transversely.

Orthoceras nummulare, Sow. Arisaig, Dr Honeyman.

Orthoceras Ibex, Sow. Arisaig, Dr Honeyman.

Orthoceras, like *O. bullatum*, Sow. Arisaig, Dr Honeyman. This and the two last are given on the authority of Dr Honeyman and Mr Salter, who also mention species of *Lituites* and *Phragmoceras*.

Articulata et Incertæ sedis.

Cornulites flexuosus, var. *gracilis*. This fossil resembles the one in the Clinton group of New York, but is somewhat more slender, and the annulations a little more closely arranged. The specimens from the rocks of New York present some variation in form, and the comparative distance of the annulations. None of them, however, are so slender as the Nova Scotia specimens. Arisaig, East River, coll. J. W. D.

Cornulites (?), n. s. East River, coll. J. W. D.

Homalonotus Dawsoni, Hall (Fig. 214). Caudal shield somewhat parabolic, obtuse at the extremity, very convex, width at the anterior

side greater than the length of the axis. Axis wider than the lateral lobes, distinguishable (in casts) from the lobes by a bending of the ribs and a scarcely perceptible depression along that line; annulations abruptly prominent; seven on the lateral lobes and nine on the axis, the anterior ones bending slightly backward at the line of division between the axis and the lateral lobe; each successive one bending more and more abruptly till the last one approaches a rectangular turn; the whole curving gently forward at their extremities, and all terminating abruptly before reaching the margin. Behind the seventh annulation the axis is marked by two more annulations, leaving nearly one-fourth of its length smooth.

This species is described from the casts and impressions of the caudal shield, so that the crustaceous covering is unknown. It is readily distinguished by the broad not prominent axis, the rectangular direction of the annulations on the axis, and their abrupt bending at the lateral furrow. An impression of a few imperfect annulations of the body shows that they are strongly elevated, much more so than in any known American species. Arisaig, coll. J. W. D.

Fig. 214.—*Homalonotus Dawsoni, Head and Pygidium.*

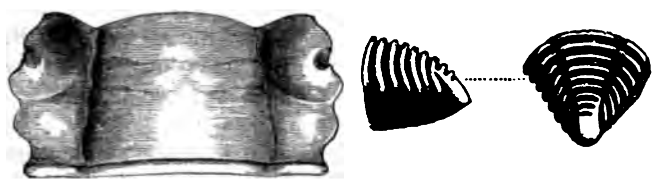
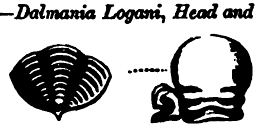


Fig. 215.—*Dalmania Logani, Head and Pygidium.*



When Professor Hall described this species, the caudal shield only was known, with some of the segments of the body. Dr Honeyman subsequently found specimens of the head. It has the posterior border nearly straight, the glabella moderately prominent and slightly wider behind than before. It descends abruptly in front, and the frontal margin appears to have risen with equal abruptness in front of the glabella and eyes. The eyes are large and prominent, and advance into a line with the front of the glabella. Some specimens have the head nearly three inches broad.

Calymene Blumenbachii, var. Caudal shield somewhat semicircular, axis very prominent, marked by about seven annulations, lateral lobes marked by five ribs, the four anterior ones bifurcating. Surface granu-

lobe. The specimens are not sufficient to make any satisfactory determinations regarding specific differences. Arisaig, East River.

Dalmania Logani, Hall (Fig. 215). The specimens are two or three imperfect cephalic shields, one preserving the palpebral lobes, and others consisting principally of the glabella, with two or three parts of caudal shields. There is a fragment of a cheek which may be of this species. Cephalic shield somewhat semicircular. Glabella ovate, wider in front and truncate behind, depressed convex; occipital ring narrow, prominent; occipital furrow bending a little forward in the middle, and curving gently backward in the middle of each side, and again turning forward; posterior furrows narrow and sharply impressed, each one extending about one-third across the glabella and curving forward at their outer extremities; central furrow linear, obscure, having a direction transverse to the axis; anterior furrow obscure; oblique to the axis, linear extending to the margin of the glabella a little forward of the eye; frontal lobe regularly rounded anteriorly. A fragment of a cheek in the same association is broad, produced posteriorly in a short strong spine, and marked by a broad sub-marginal groove. Caudal shield somewhat semi-elliptical, convex, acute behind, axis very prominent, rounded and marked by about eight annulations, which are gently curved backward at the extremities; lateral lobes with six simple flattened ribs which terminate in a thickened border, and separated from the axis by a strongly defined furrow; extremity abruptly pointed.

The glabella of this species more nearly resembles *Phacops* in the general form and faintly impressed furrows, of which the posterior one is conspicuous. The form of the palpebral lobe, and the absence of tubercles at the base of the glabella, together with the form of the caudal shield, ally it with *Dalmania*, and it may be compared with *D. Phillipsi* of Barrande, but has a more pointed caudal shield, and the cheek, if correctly referred, is prolonged in a posterior spine.* Arisaig, coll. J. W. D.

Proetus Stokesii (?), Edwards. Arisaig, coll. J. W. D.

Homalonotus Knightii, Konig. Arisaig, Dr Honeyman.

Phacops Downingii, Salter. Arisaig, Dr Honeyman. The two last species are given on the authority of Dr Honeyman's and Mr Salter's lists.

Beyrichia pustulosa, Hall (Fig. 216). Valves unequally semi-oval, a little more than once and a half as long as wide; surface marked by three prominent ridges; central, anterior, and posterior. The central one is a single oblong oval tubercle, which is directly

* Attached to a fragment of one of these trilobites is a small *Spirorbis*. It is dextral, with two to three turns, and rounded concentric wrinkles on the last whorl.—J. W. D.

transverse to the dorsal margin and a little nearer the anterior side. The anterior ridge consists of a single highly elevated, rounded or papillose tubercle near the dorsal margin, and an elongated elliptical tubercle placed obliquely near the antero-ventral margin, and in older specimens sometimes swelling and spreading over the margin. The posterior ridge rises near the dorsal margin, and making a slightly broader curve than the posterior end of the valve approaches the ventral margin at the centre: the ridge is high and angular with a small prominent tubercle at the dorsal extremity, and from four to six smaller spine-like tubercles along its curve. The central ridge or tubercle is separated from the lateral ridge by a distinct furrow, and its continuation from the base of the tubercle passes between the lower ends of the two lateral ridges. Ventral and lateral margins with a narrow thickened rim.

This species resembles very nearly the *B. tuberculata* of Kloden, as described and figured by Mr T. Rupert Jones. In our specimens the dorsal angles are more rounded; the posterior ridge at its base is never extended beyond the middle of the valve, and is marked on its crest by several small spine-like tubercles. The anterior ridge is usually more extended along the ventral margin in our specimens, and the furrow is better defined, while the tubercles are never flattened above or overhanging the base as shown in the European specimens. Smaller specimens, which appear to be the young of this species, present some slight variations of surface markings, but show less difference than the young of *B. tuberculata*. Arisaig, coll. J. W. D.

Fig. 216.—*Beyrichia pustulosa.*

Fig. 217.—*B. equilatera.*

Beyrichia equilatera, Hall (Fig. 217). Nearly equilateral, very convex, marked by three smooth or nearly smooth ridges. The central ridge is an oblong tubercle reaching from near the dorsal margin a little more than half way to the ventral margin. The posterior ridge is a little larger, but scarcely differing in form from the anterior one, its ventral extremity terminating beneath or a little in advance of the middle of the central tubercle. The furrow is narrow, but well defined on the two sides of the central tubercle, and becoming shallow in its passage to the marginal furrow; ventral and lateral margins thickened. Arisaig, coll. J. W. D.

Leperditia sinuata, Hall. Minute, sub-ovate, anterior end narrow, dorsal line one-third shorter than the length of the valve; an extremely minute tubercle near the anterior end. Centre extremely convex or

ventricose; ventral margin near the posterior end a little sinuous, or indented from the inner side. Surface smooth under an ordinary lens.

Two specimens only of this species have been observed, both of them having the same dimensions. Arisaig, coll. J. W. D.

Tentaculites distans, var. The specimens under examination do not present any important points of difference from those of the Clinton group in New York. In the Nova Scotia specimens there are numerous annulations near the apex, which are not observable in the New York specimens. Arisaig, coll. J. W. D.

Note on the Character of the Metamorphic and Igneous Rocks of the Upper Silurian District.

These rocks introduce us more distinctly than the previously described Devonian series to those changes in sedimentary deposits known to geologists by the term metamorphism, and which, whatever views may be entertained as to the precise causes of such changes in the case of particular rocks, may be stated in general terms to be the results of heat and pressure acting in the presence of moisture at great depths in the interior of the earth. In so far as the Upper Silurian rocks of Nova Scotia and New Brunswick are concerned, the alteration they have undergone and the unstratified masses introduced among them, may be grouped under the following general statements:—

First, Some portions consist of shaly, sandy, and calcareous deposits, considerably hardened and much disturbed, yet retaining abundance of fossil shells and other evidences of a marine origin. In these, with the exception of mere hardening, the changes which have been induced on the sediments are limited to the following:—(1.) The production of slaty structure, by which the rocks are rendered fissile in planes different from those of their true bedding. This is termed *slaty* structure as distinguished from mere shaly lamination, and is believed to be due principally to mechanical pressure. (2.) In connexion with this, much distortion of the fossils, so that their proportions and general forms cannot be relied on as specific distinctions. (3.) The production, to a greater or less extent, of crystalline structure; for example, in the New Canaan beds fossils occur in rocks which have to a great extent been converted into micaceous schists.

Secondly, Other portions, originally no doubt similar to those now less altered, are highly metamorphosed, and are not only hardened and schistose, but have assumed a crystalline structure, so that instead of the mud, sand, and similar materials of which they were originally composed, we find more or less crystalline aggregates of quartz, mica,

felspar, hornblende, chlorite, and other minerals, which must have been produced by re-arrangement of the substances contained in the sediments, under the influence of chemical agencies. Such fossils as may have existed in these rocks have entirely disappeared, or may in some instances be seen to be replaced by mere nests of calcareous crystals or even by crystals of garnet. In the district now under consideration, these metamorphic rocks may be grouped under the following heads, each of which, however, includes many varieties graduating into each other:—(1.) *Quartzite*, or a hard silicious rock produced from the alteration of sandstone or arenaceous shale; (2.) *Gneiss*, a stratified rock composed of quartz, felspar, and hornblende, or quartz, felspar, and mica, and a product of the metamorphism of conglomerates and other mixed sediments; (3.) *Micaceous* and *chloritic slates*, consisting of quartz and mica, or quartz and chlorite, and apparently a result of the further alteration of clay slates, into which the micaceous schists graduate; (4.) *Diorite* or Hornblendic greenstone, a crystalline mixture of the mineral hornblende with felspar, often laminated or rudely stratified. These rocks may be merely altered mud-rocks or shales, but in many cases they may have been originally volcanic tufas or ash-rocks. (6.) *Compact Felspar* and Felspar porphyry, containing small isolated felspar crystals in a paste of more compact material of similar composition. Many rocks of this character appear to be stratified, and are probably metamorphosed clays. (7.) *Crystalline Limestone* or Marble, usually white and sometimes with crystals of tremolite and patches of serpentine. Owing to the small amount of calcareous matter in the original sediments, this kind of rock is not largely developed in the Upper Silurian districts.

All of the above are stratified and metamorphic. With these are other rocks in masses or veins either intrusive, and of the nature of volcanic rocks, or "indigenous" products of the fusion of sedimentary rocks *in situ*. These igneous rocks, as they may be called, though probably of similar origin with the trap of the Triassic and Carboniferous systems, differ somewhat in composition and appearance. They are mostly coarser grained or more crystalline, indicating that they are less superficial, and hence have cooled more slowly. Hornblende usually replaces the Augite of the trap. Felspar, which is the pure white or flesh-coloured part of ordinary granite, exists in greater abundance than in trap. Quartz or uncombined silica is also often present in considerable quantity. Rocks of this class are very variable in their composition and appearance, hence it is difficult to give them accurately distinctive names, and geologists entertain different opinions as to the amount of internal heat, or igneous action proper, involved

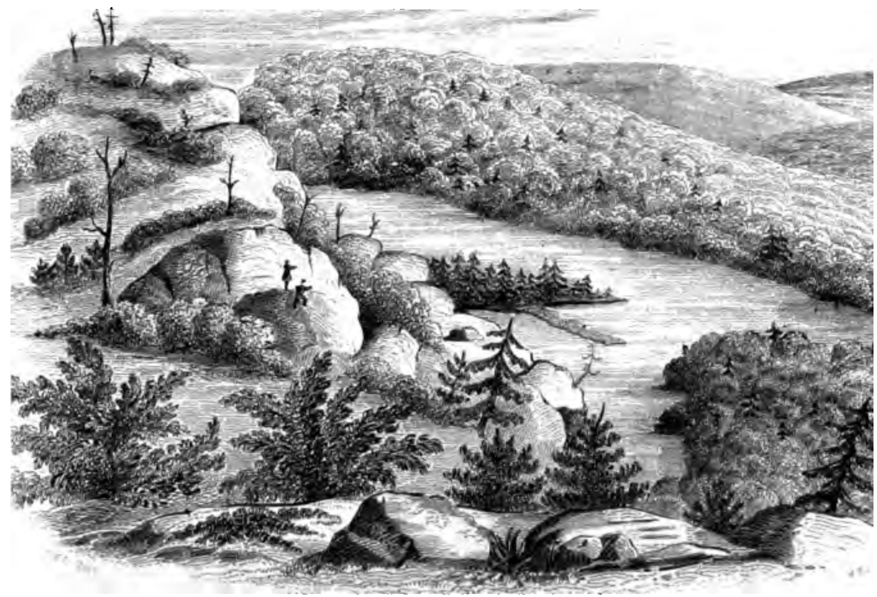
in their production, and also as to the question whether they are derived from deep-seated sources under the stratified rocks, or have been produced from the fusion or semi-fusion, with aid of heated water, of portions of the sediments themselves. That in some cases they are at least partially of the latter character is, I think, evident from the manner in which they appear to replace stratified rocks in their line of strike, or to occur in bedded masses among them, and also from their apparent relation in mineral character to the associated igneous rocks. On the other hand, in their frequent intrusion into the fissures of the aqueous rocks, they are certainly in many cases to be regarded as eruptive rocks of unknown and deep-seated origin. Dr Hunt has very fully considered these points in reference to similar rocks in the Reports of the Geological Survey of Canada. In the district now under consideration, the following terms may serve for the designation of the more important rocks of this class:—

Unstratified Diorite or *Hornblendic Greenstone* consists of hornblende and felspar, sometimes in large distinct crystals of black or green hornblende and white felspar, and in every gradation of crystalline texture between this and a gray or greenish rock in which the separate crystals are scarcely distinguishable. When there are large distinct felspar crystals imbedded in the mass, it is named *Porphyritic* greenstone.

Unstratified Compact Felspar or *Felsite* is a rock consisting of the materials of felspar with some quartz, but not distinctly crystalline. It is sometimes fine-grained and flinty in aspect, and in other cases dull and rough in its fracture, approaching to the rocks called *Trachyte* and *Claystone*. Its colours are usually dull-gray, reddish-brown, and greenish. It often contains scattered distinct crystals of lighter coloured felspar, and is then *Felspar Porphyry*.

Granite, composed of distinct crystals of quartz, felspar, and mica. Granite is less abundant in this district than in the Lower Silurian area, next to be noticed, and the varieties which occur are often less perfectly crystalline, or have a less resisting felspar, causing them to decompose readily.

Syenite consists of distinct crystals of reddish, gray, or white felspar, with a smaller quantity of dark-coloured hornblende and some quartz—the whole forming a material somewhat similar to granite, with which it is often confounded. We may associate with this rock, or with greenstone and compact felspar, a number of nameless rocks in which crystalline felspar forms the chief ingredient, with or without quartz and hornblende.



CHAPTER XXIV.

THE LOWER SILURIAN PERIOD.

LOWER SILURIAN OF NOVA SCOTIA—GOLD—LOWER SILURIAN OF NEW BRUNSWICK—"ACADIAN GROUP"—USEFUL MINERALS—PRIMORDIAL FOSSILS.

To this geological age I have referred, principally on evidence of an inferential character, the extensive belt of metamorphic sediments extending along the coast of Nova Scotia from Cape Canseau to Cape Sable. On similar grounds certain extensive areas of metamorphic rocks in New Brunswick have been regarded as belonging to this period; and very recently the discovery of a rich primordial fauna in some of these beds near St John has confirmed this view in regard to a portion of these areas; while in Northern New Brunswick the resemblance of the beds to those of the "Quebec group," and their relation to the Upper Silurian beds, tend to give similar confirmation.

In describing these districts, we shall first sketch the character and distribution of the Atlantic coast series of Nova Scotia, with the important discoveries of gold which have given to it so great economic importance, and shall then proceed to notice the rocks of similar age in New Brunswick, with the very remarkable fossils—the oldest known in Acadia—which have recently been discovered in them.

1. *Lower Silurian of the Atlantic Coast of Nova Scotia.*

This series extends continuously, with prevailing east and west strike, from Cape Canseau to the middle of the peninsula at Halifax Harbour; thence it continues with prevailing north-east and south-west strike to the western extremity of the province. Its most abundant rocks are coarse clay slate and quartzite in thick beds. In some districts the slates are represented by mica schist and gneiss, and interrupted by considerable masses and transverse bands of intrusive granite. It has afforded no fossils; but it appears to be the continuation of the older slate series of Mr Jukes in Newfoundland, which has

afforded trilobites of the genus Paradoxides. These fossils would indicate a position in the lower part of the Lower Silurian series, possibly on the horizon of the Potsdam sandstone or Lingula flags. If so, the Lower Silurian limestones are either absent or buried by the unconformable superposition of the next series, or of the carboniferous beds which in some places immediately adjoin these older rocks. It is to be observed, however, that the mineral character of the rocks themselves very closely resembles that of some portions of the "Quebec group" of Sir William Logan. If coeval with this, they would be somewhat higher in the Lower Silurian scale; but I think it may be safely affirmed that no newer group than the Quebec series can claim them with any show of reason. We may therefore in the meantime regard these rocks as probably representative of some portion of the lower part of the Lower Silurian, but without venturing to assign them to any definite horizon, and admitting the possibility that future researches may establish differences sufficient to divide them into distinct formations. More especially in the western part of Nova Scotia, where this band attains to great breadth, I entertain the hope that a continuous sequence may be one day ascertained from the Devonian to the base of the Lower Silurian.

Large though this district is, there is by no means so great a variety in its rocks as in those of the district last described; and most of them are nearly related to each other, being composed of the same materials variously arranged. I shall notice them specially with reference to their differences from those of the Upper Silurian series.

1. *Granite*, as it occurs in this district, is a crystalline mixture of white, or more rarely flesh-coloured, felspar,* with smoky or white quartz and gray or black mica. It varies in its texture, and is sometimes porphyritic; that is, it consists of a base of fine-grained granite, with large crystals of felspar forming distinct spots. It often contains altered fragments of the neighbouring slates, and penetrates in veins into the adjoining rocks, which in its vicinity are always more highly metamorphosed than usual.

2. *Gneiss* is a fine-grained granitic rock, arranged in laminæ or layers. It is unquestionably here, as in the Upper Silurian district, a product of the metamorphism or "baking" of sedimentary rocks by heat and water, and in this series it almost invariably holds mica and not hornblende.

3. *Mica slate* consists of quartz and plates of mica, forming a highly fissile rock with shining surfaces, and usually of a gray or silvery

* Orthoclase, but with soda as well as potash. The granite of Annapolis, mentioned in last chapter, has in some places reddish quartz.

colour. In the coast metamorphic district of Nova Scotia, it appears in many and beautiful varieties. Talcose, chloritic, and hornblendic slates are comparatively rare in this district.

4. *Quartz rock*, or *Quartzite*, consisting of grains of flinty sand fused together, and with occasionally a little mica, occurs in this series in very massive beds.

5. *Clay slate*, or argillaceous slate, abounds, and is usually in this district of gray and black colours, and varying very much in texture and hardness. It often presents indications of the original bedding in different planes from those of the lamination, the latter being an effect of causes acting at a time posterior to the original deposition, and, as already stated, pressure was probably the most efficient of these causes.

Between these rocks there are many intermediate forms. Granite often passes by imperceptible gradations into gneiss—this into mica slate—this into quartzite—and this into coarse or flinty clay slates. There appears every reason to believe that all these rocks, except the granite, are merely variously metamorphosed forms of common sandstones and clays.

The Lower Silurian rocks form a continuous belt along the Atlantic coast of the province, narrow at its north-eastern extremity, and attaining its greatest development in the western counties. Its southern or coast side has a general direction of S. 68° W.; its inland side, though presenting some broad undulations, has a general direction of about S. 80° W. Its extreme breadth at Cape Canseau, its north-eastern extremity, where it is bounded on one side by the ocean, and on the other by Chedabucto Bay, is only about eight miles. In its extension westward, it gradually increases in width, until at the head of the west branch of the St Mary's River, eighty miles distant from Cape Canseau, it is about thirty miles in breadth. In the western counties it again increases in width, and though its northern boundary is not well ascertained, its breadth can scarcely be less than fifty miles. Its total length is 250 miles.

The general character of the geology of this district may be very shortly stated. It consists of thick bands of slate and quartzite, having a general N.E. and S.W. strike, and highly inclined. In several places large masses of granite project through these rocks, and in their vicinity the quartz rock and clay slate are usually replaced by gneiss and mica slate, or other rocks more highly metamorphosed than usual. Bearing in mind this general character, we may proceed along this district from west to east, noting the more interesting points of its structure as they occur.

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The Lower Silurian rocks form a continuous belt along the Atlantic coast of the province, narrow at its north-eastern extremity, and attaining its greatest development in the western counties. Its southern or coast side has a general direction of S. 68° W.; its inland side, though presenting some broad undulations, has a general direction of about S. 80° W. Its extreme breadth at Cape Canseau, its north-eastern extremity, where it is bounded on one side by the ocean, and on the other by Chedabucto Bay, is only about eight miles. In its extension westward, it gradually increases in width, until at the head of the west branch of the St Mary's River, eighty miles distant from Cape Canseau, it is about thirty miles in breadth. In the western counties it again increases in width, and though its northern boundary is not well ascertained, its breadth can scarcely be less than fifty miles. Its total length is 250 miles.

The general character of the geology of this district may be very shortly stated. It consists of thick bands of slate and quartzite, having a general N.E. and S.W. strike, and highly inclined. In several places large masses of granite project through these rocks, and in their vicinity the quartz rock and clay slate are usually replaced by gneiss and mica slate, or other rocks more highly metamorphosed than usual. Bearing in mind this general character, we may proceed along this district from west to east, noting the more interesting points of its structure as they occur.

The county of *Yarmouth* presents a succession of low ridges of slate and quartz rock, separated on the coast by narrow inlets, and inland by valleys, often containing lakes and bogs. The prevailing strike appears to approach more nearly to north and south than in other parts of this district. Near the town of Yarmouth it was observed to be N. 20° E., and at Pubnico nearly N. and S. Near the town of Yarmouth there are hornblende and chlorite slates, and inland, in the direction of Carleton, clay slates appear to prevail. Veins of white quartz abound in these rocks. On the east side of the Tusket River quartz rock prevails, and forms a stony country. Toward Pubnico, mica slate and micaceous quartz rock appear, and are traversed by granitic veins, leading us to the massive granite of Shelburne county. Granite is also said to occur inland at Kempt; but I have not visited this place.

On entering *Shelburne*, we find granite at Wood's and Shag Harbours, and extending inland for some distance. At Barrington there is still abundance of granite and mica slate, with strike N. 23° E. At Port La Tour, the mica slate and gneiss abound in large prismatic crystals of a greenish magnesian mineral, allied to steatite. These crystals, which are perhaps pseudomorphous, project from the weathered surface of the rock. At the town of Shelburne there is abundance of a fine-grained granite of excellent quality, and toward the mouth of the harbour gneiss occurs, with small crystals of garnet; its strike is S.W. Veins of coarse-grained granite penetrate these rocks, and in some places these veins present the singular variety to which the name *graphic granite* has been applied, from its resemblance to written characters. In this variety of granite, quartz and felspar alone are present, and the quartz in hardening has arranged itself in plates between the felspar crystals, so that when the mass is polished, the sections of these quartzose plates present the appearance of ancient Samaritan on modern phonographic writing. In the graphic granite of Shelburne, the characters are in gray quartz, and the ground is white or flesh-coloured felspar. In surface gravel, near the town of Shelburne, I found pebbles of the beautiful mineral rose-quartz, but did not observe it in place.

At Jordan and Sable Rivers, in the eastern part of this county, gneiss and mica slate appear in many fine varieties, and contain abundance of crystals of *Staurotide;* and Schiller spar and talc sometimes enter into the composition of these rocks as well as mica.

On entering *Queen's* County we find granite at Port Joli and Port Mouton, and toward the town of Liverpool these give place to quartz rock, which, with some beds of micaceous slate, here occupies a great

breadth, and produces a very stony and barren country, encumbered with large boulders. This rocky surface, at the distance of about ten miles from the coast, gives place to a fine undulating wooded country, supporting populous agricultural districts, and traversed by the Liverpool and Port Medway, two of the largest rivers in the province, with numerous and large lakes at their sources. The source of the Liverpool River is in the high lands near Annapolis, not more than ten miles from the shores of Annapolis Basin; and the distance in a direct line from its source to its outlet is more than fifty miles. Lake Rosignol, one of the many fine lakes that stud its course, is twelve miles in length, and five in its greatest breadth.

The prevailing rock in this *northern district* of Queen's County is clay slate, having a general south-west strike, and almost everywhere polished and marked with diluvial striæ. This inland slate district appears to be continuous with that of Lunenburgh on the east, and that of Yarmouth on the west; so that in this part of the province the granitic rocks appear to be confined to the vicinity of the Atlantic coast, and to the inland hills near the Annapolis Valley, while a fine undulating slate country, diversified with numerous lakes, occupies the interior. In such a situation, more modern rocks than those of the Atlantic coast may be expected to occur. I searched in vain, however, for fossils in the northern district of Queen's, but obtained from a gentleman resident there a fragment of hard quartzose rock, which he believed to have been found *in situ*, and which contains some fragments of fossil shells, not certainly determinable, but apparently resembling Upper rather than Lower Silurian forms.*

On the eastern side of Queen's County, the quartzite and mica slate are associated with granite, and beyond this they give place to clay slate, which occupies the county of *Lunenburgh* as far as Cape Aspatogoen, and inland as far as I have any acquaintance with its structure. The country here has much of the aspect as well as the agricultural value of that of Northern Queen's, and presents in these respects a favourable contrast to most other parts of the Atlantic coast. The slates of this county are usually blue or black, and often charged with iron pyrites, which, when weathered, gives them an intense rusty yellow colour. This appearance is especially prevalent in some places in the western part of the county. Their strike is S.W. and N.E.

It is on the margin of this slate district of Lunenburgh, and at the bottom of a deep bay penetrating into it, that the limited tract of Lower Carboniferous rocks, already noticed as occurring at Chester Basin, appears. These Carboniferous beds dip at a moderate angle

* Poole, Report on Gold-fields, 1862, mentions similar fossils, and gives many additional facts as to geological structure.

S.S.E., and give no evidence that this metamorphic district has suffered any considerable disturbance since their deposition. At Mahone Bay, however, I observed a large quantity of fragments of reddish amygdaloidal trap, which cannot be far from their original site, and probably belong to some trappean eruption of the Carboniferous period.

Aspatogoen, which is a rocky promontory, about 500 feet in height, separating Mahone from Margaret's Bay, consists, according to Mr Poole, principally of quartzite and slate with granite, and is apparently at the extremity of a thick dike or ridge of the latter rock, extending to the northward across the stratification of the country. It is the highest land on the Atlantic coast of Nova Scotia.

Margaret's Bay is another deep indentation, between Aspatogoen and a broader but lower tract of granitic rock, extending to the north-west arm of *Halifax* Harbour. Around Margaret's Bay, as at Chester, there are small patches of Lower Carboniferous rocks; but these are for the most part concealed under granitic debris drifted from the neighbouring districts.

The granitic district east of Margaret's Bay, and terminating at Cape Sambro, has a north and south direction. It contains several varieties of common and porphyritic granite, with veins of coarse-grained, and more rarely of graphic granite. Near the north-west arm there are good opportunities of observing its junction with the slates which succeed it to the eastward. The slate is not here converted into mica-slate; but, in the vicinity of the granite, it is hardened and rendered crystalline, and in some places passes into a rock resembling hornblende slate. In other places it appears as a hard flinty slate, filled with slender prismatic crystals apparently of staurotide. In close contact with the granite the slates assume the appearance of gneiss, and are traversed by granite veins, which often contain crystals of schorl and garnet, indicating that these veins received additions of foreign substances, as boracic acid, iron, etc., in passing through the stratified rocks. The granite itself is here porphyritic, and occasionally contains fragments of the rocks through which it has passed, fused into gneiss and mica slate. All these appearances indicate that the intensely heated and molten granite was the cause of the alteration of the slates.

Eastward of Halifax, the whole country as far as Musquodoboit River, and northward to the northern limits of this district, consists principally of alternate thick beds of coarse clay slate, often highly pyritous, and quartzite, granite bosses projecting through it in a few places. The strike of the beds in this part of the province approaches

more nearly to E. and W. than at the places previously described. At many localities, however, it retains its usual S.W. and N. E. direction. Thus, at the tower at Point Pleasant, the strike of the bedding is N. 30° E., and that of the slaty structure N. 75° E. On the shore near the same place, the strike is N. 60° E., and the dip is to the north-west. Nearer the city, the dip of the true bedding is in some places to the south, the strike being nearly E. and W. The cleavage is, however, here much better defined than the bedding, which is indicated principally by lines of different colour, and appears to undulate very much. On the road from Halifax to Windsor, at Dartmouth, and at Musquodoboit River and Harbour, the strike both of the bedding and slaty cleavage approach to E. and W. magnetic.

On the Musquodoboit River, granite reappears, and extends to the eastward as far as the Great Ship Harbour Lake. Beyond this place, as far as the extreme eastern end of the district, quartzite and mica-slate, with masses and bands of granite and gneiss, prevail; but I have scarcely any knowledge of their distribution, except in the vicinity of the St Mary's River, and in the peninsula of Cape Canseau.

The valley of the lower St Mary's River is a rugged and rocky gorge, excavated at right angles to the structure of the country, and affording an outlet for the waters of several streams that, seeking a passage across the hilly barrier of the metamorphic district, form a small lake at the entrance of this common channel. At the mouth of the river, a considerable breadth is occupied by micaceous slates, with bands of quartzite. The strike of these rocks is N.E. and S.W., and in the places where I observed their dip, it is to the S.E. at high angles. Behind the village of Sherbrooke, and two miles eastward of the river, a mass of granite projects through these rocks, but does not occur in the river section. This granite is well seen in the lakes emptying into Indian Harbour. On the river itself, the slates and quartz rock continue with considerable regularity of strike; the latter becoming quite predominant, and rising into considerable eminences as it approaches the "Forks," where it suddenly descends into the Carboniferous valley of the St Mary's.

Eastward of the St Mary's River, this district gradually narrows toward its extremity at Cape Canseau, but still presents on its northern margin a range of abrupt eminences, and on the south a low, rugged, and indented coast. Indeed, the steep rounded swell with which its northern side descends at the head of Chedabucto Bay, and the precipitous headlands beyond Crow Harbour, are the finest appearances in point of scenery which it presents in its whole extent.

A large part of the peninsula terminating at Cape Canseau, is

occupied by white fine-grained gneiss, with veins and masses of granite, sometimes of a reddish colour. There is also much mica slate, and dark-coloured clay slate, filled with crystals of the singular mineral chiastolite or cross-stone. Near the extremity of Cape Canseau specimens of this mineral occur, of a reddish or fawn colour, three or four lines wide, and exhibiting the characteristic black cross in considerable perfection. I have not found this mineral in any other part of Nova Scotia.

Having thus shortly surveyed this large though little explored district, I may notice the probable arrangement of its beds, and the causes of their present condition, the waste it has undergone, and the materials it has contributed to newer formations, its useful minerals, and the peculiarities of its surface and soils.

The beds of the Lower Silurian district present a considerable uniformity of strike, in the direction already mentioned, along the whole coast; a fact which, in addition to the statements above made, is curiously indicated by a table of compass dips and strikes of the rocks on this coast now before me, and for which I am indebted to H. Poole, Esq. In this table, out of eighty-three observations at various places between Halifax and Yarmouth, the strike is between W. and S. in seventy-three instances, and in a great many of these not far from S. 45° W. The dips are, however, very variable, and it is, in many cases, not easy to distinguish them from the slaty structure, which often gives planes much more distinct than those of the bedding. On carefully examining a section, such as, for example, that already referred to at Halifax Harbour and its vicinity, it will be found that the beds undulate in synclinal and anticlinal curves, often of no great magnitude, so that they are frequently repeated within a few miles. This structure has been worked out in some detail by Mr Campbell * in the country between Halifax and Windsor. In other sections, however, as, for example, in that of the St Mary's River, there appears to be an enormous thickness of beds with a uniform dip. Reasoning on these facts, we arrive at the conclusion that the alternations of quartz rock and clay slate constitute one very thick formation having probably a predominance of quartzite below and of slate above; but whether the mica schist and gneiss which occur on the peninsula of Cape Canseau, and also in Queen's County and Shelburne, and the chloritic beds of Yarmouth, are to be regarded as continuations of this series, differently changed by metamorphism, or as portions of other members of the Lower Silurian or of still older deposits, remains uncertain. To settle this question,

* Report on Gold Mines of Nova Scotia. Journals of Assembly.

detailed lines of section should be run across the district at several places, and some of the more decided outcrops of quartz rock should be carefully traced.

It is interesting to note the points of difference between these rocks and the more highly altered portions of the Upper Silurian series, as described in a previous chapter. Quartz rock occurs in both; but it exists in greater abundance and in more massive beds in that last described. Clay-slate also occurs in both, but in the first described it presents much greater variety of colour and texture; it is associated with many coarse beds, which have been usually named graywacké, and graywacké slates, and in many places it approaches to the character of a steatitic slate. These inland slates are also highly metalliferous, abounding in veins of iron ore, and containing at least one great conformable bed of that mineral, while copper ores also appear in a variety of places. They also contain numerous calcareous bands and layers of limestone. In all these respects the slates of the Atlantic metamorphic district are strikingly different. They are thick-bedded and uniform in their appearance, destitute of calcareous matter, and with few metallic minerals, except disseminated crystals of iron pyrites, and the veins of auriferous quartz, which are nearly if not altogether peculiar to this formation as compared with the other. They also pass into micaceous slate, which is rarely seen in the other district. These and other differences of detail must prevent any observer acquainted with both districts from supposing their rocks to be geologically equivalent.

The metamorphism of these rocks must have occurred prior to the Carboniferous period, and there can be no doubt that the granitic rocks have been the agents in affecting it, if they are not themselves portions of the stratified beds completely molten and forced by pressure against and into the fissures of the neighbouring unmelted rocks. It will be observed that many of these granitic masses have a north and south direction, whereas the general strike of the beds is N.E. and S.W. This would indicate either that the lines of greatest igneous intensity and intrusion of molten matter had no direct connexion with the elevating and disturbing forces, or that these granitic masses are merely outliers from a great N. E. and S.W. granitic axis, at one time the summit of a line of hills of which only the margin remains visible, the axis itself having sunk again into the bowels of the earth, before the commencement of the Carboniferous period.

The general direction of the strike of this district coincides with that of the Lower Silurian bands of New Brunswick and of the Lower

St Lawrence, and the movements of its beds may have begun in connexion with the disturbances which Logan and others have shown to have occurred at the close of the Lower Silurian period; but the intrusive granite appears to be continuous with that of Devonian age described in a previous chapter.

Whatever view may be taken of the age of the granitic rocks of this group, it is certain that they are strictly *hypogene* rocks, that is, that they belong to the deep-seated foci of subterranean heat, and are not superficial products of volcanic action. They are substances such as we might expect to find, could we penetrate miles below the surface, beneath modern volcanoes. They were therefore probably at one time buried deeply, and have been brought up by movements of dislocation, and by the removal of their superficial portions by aqueous agents. They have without doubt furnished much of the material that has been employed in building up the more recent formations of the country.

This leads to the question, Can we discover in the subsequent rock formations evidences of such an origin, and can the changes which these derived materials have undergone be satisfactorily explained? This subject, the genealogy of rocks as it may be termed, is of some interest, and I may glance at it in its bearing on the geology of Nova Scotia.

The granite of Nova Scotia and its associated gneiss and mica-slates are among the oldest rocks found in the province, and we may therefore take them and their derived rocks for illustrations. The products of the decomposition of granite are quartz sand, scales of mica, and fine clay which results from the decomposition of felspar. Such materials, when washed down and deposited in water, will form coarse and fine sandstones, micaceous sandstones and flags, arenaceous and argillaceous shales; and these may, by heat and pressure, be converted into quartzite, mica slate, and clay slate. From pure white granite the derived detritus would be colourless or nearly so. But the mica and felspar of many granites contain iron, and the sulphuret of iron is also present in some granites. In these cases the derived sediment will have a yellow or buff colour, from the presence of the yellow oxide of iron; or in some cases the clay may have a red colour, from the peroxide of iron present in red felspar. Of course, when the granites contain hornblende or are syenitic, much more iron may be present in the derived sediment. In nature nearly all soils of granitic origin are more or less coloured in these ways. In this manner, buff, brown, and red clays, and buff and brown sandstones may be produced.

Igneous action may produce still farther changes. The yellow sand which results from the decay of granite is merely stained on the surface by the ferruginous colouring matter, and a very slight degree of heat is sufficient, by expelling the water of the iron rust, to convert this yellow stain into a bright red. This change is superficially produced by forest fires, and might readily occur when decomposing granitic rocks have been subjected to the influence of intensely heated or molten masses, with access of air or water. Red sands and clays produced in this way, and washed into the sea, become red sandstones and shales. Such red deposits are, however, liable to still farther change. If long washed about in the sea, the red coat is worn from the sands and added to the fine clays, so that whitish sandstones may alternate with red shales. If vegetable or animal matter is present, the changes of colour referred to in treating of the marsh mud may take place, and dark-coloured or gray beds may result, or greenish stripes and bands may appear in the mass of red deposits.

Clays and sands thus deposited may be hardened into rock by pressure, by heat, or by cementing matter introduced by the percolation of mineral waters.

It will thus be perceived, that from the granitic rocks it is possible to deduce a variety of yellow, brown, and gray sandstones and shales, quartzites, and slates. Many other rocks, however, beside granite have been decomposed, especially to form the more modern deposits; hence more complicated results than those above stated have been produced. Enough has, however, been said to show how much derived deposits may differ in appearance from those which have furnished their materials; and also the mode in which the waste of the older rocks has been disposed of. These facts also serve to show the enormous waste or denudation which the older rocks must have suffered in order to furnish the materials of the derived formations, for example, of the Carboniferous beds. They farther illustrate the connexion of red sandstones with periods of igneous activity, and the prevalence of gray and dark-coloured sediments at times when deposition has been slow and organic matter abundant.*

With respect to surface and industrial capabilities, the different rocks occurring in this district present very various aspects. The clay slate often has a regular undulating surface, and a considerable depth of shingly or clay soil of fair quality, though usually deficient

* See on this subject the author's Paper on "The Colouring Matter of Red Sandstones," Jour. of Geol. Soc., and page 24 *supra*.

in lime. These slate districts, however, often contain beds of quartz rock which form rocky ridges, from which boulders have been scattered abroad, and which, by damming up the surface waters, produce lakes and bogs,—an effect also often produced by the ridged structure of the slate itself, and the impervious subsoil which it affords. Wherever, as for instance in Northern Queen's and Lunenburgh, the slate is sufficiently elevated for drainage, and not encumbered with surface stones, it supports fine forests and valuable farms. Where quartz rock prevails, the soil is almost invariably extremely stony and barren. Instances of this occur in Southern Queen's, near Halifax, and in the hills near the St Mary's River. The mica slate is little better, for though it does not furnish fragments to cumber the surface, it scarcely affords any soil.

The granite and gneiss in some places appear in precipitous hills of considerable elevation, and in others form low and uneven tracts. Their decomposed surface affords a sandy quartzose soil, often strewn with large rounded blocks of granite, which in some instances cover the whole surface, so that a granitic hill appears to be merely a huge mound of boulders. This appearance results in most cases from the nodular character of the granite, or from its consisting of great balls of hard resisting rock, united by a material of more perishable character. Where the granite or gneiss is wholly of a resisting character, its surface is sometimes almost entirely bare, or coated only with a layer of peaty vegetable soil. This occurs to a great extent in the peninsula of Cape Canseau. The granitic soils in their natural state often support fine groves of oak and other deciduous trees; but the bare summits, destitute of soil, are clothed only with stunted spruces and various shrubs and mosses. Where the original vegetation has been destroyed by fire, the granite hills often become perfect gardens of flowering and fruit-bearing shrubs. I have collected in a day in August, on a single granitic eminence, sixteen species of edible wild fruits. The alkaline matter afforded by the waste of the granite is especially favourable to the growth of these plants as well as of ferns; fields of which (chiefly the common brake, *Pteris aquilina*) may be seen in the valleys among the granitic hills to attain the height of four feet.

Useful Minerals of the Lower Silurian of Nova Scotia.

Gold.—At the date of the publication of "Acadian Geology" in 1855, no actual discovery of gold in Nova Scotia was known to have been made. At that time I could only indicate the possibility that such discoveries might be made, and the most probable localities;

and even in this I had not the advantage which would have been afforded by the discoveries subsequently made by Sir W. E. Logan as to the true age of the gold-bearing rocks of the Chaudière district in the province of Quebec. At that time I ventured to hint at these probabilities in the following terms:—

"Since the gold discoveries in California and Australia, reports of similar discoveries have locally arisen at different times in Nova Scotia; but, so far as I am aware, have always proved deceptive. Iron pyrites, or the bright golden scales which occur among the debris of granite containing black ferruginous mica, have usually been mistaken for the precious metal. Quartz veins, however, occur abundantly in some parts of this district, and it would not be wonderful if some of them should be found to be auriferous. It is, however, much more probable that such discoveries may be made in the inland metamorphic district described in last chapter than in that now under consideration, as its rocks bear a much closer resemblance to those of the auriferous districts in other parts of America. Most parts of Nova Scotia have been too well explored to leave much probability that any extensive surface deposits of the precious metal exist, but that it does not occur in small quantities cannot with safety be asserted, until careful trials of the sands and gravels of the streams flowing from the metamorphic districts shall have been made. The gold deposits of the River Chaudière in Lower Canada afford an instance in which, while individual search has proved quite unprofitable, washing operations on a large scale with the aid of machinery have repaid the labour and capital employed. Unless some accidental discovery should indicate a promising locality, it would be unwise for individuals to engage in such trials; but if a public survey should be undertaken, they would form a part of its duties." At that time, as some absurd articles had appeared in the public prints predicting the discovery of gold in very unlikely localities, and some excitement had been caused thereby, I feared even to say this much.

Public attention was first attracted to the existence of gold in Nova Scotia in 1860. Previously to that time, though Mr J. Campbell had found indications at Laurencetown, and accidental discoveries had been made by others, nothing practical resulted. The circumstances and place of the first discovery are thus stated in a Report of the Hon. Joseph Howe:—

"In March this year, a man, stooping to drink at a brook, found a piece of gold shining among the pebbles over which the stream flowed. He picked it up, and searching found more. This was about half a mile to the eastward of the debouchment of Tangier

River, a stream of no great magnitude, taking its rise not very far from the sources of the Musquodoboit, flowing through a chain of lakes which drain, for many miles on either side, a rugged and wilderness country, and falling into the Atlantic about forty miles to the eastward of Halifax. These discoveries were soon followed by others at Musquodoboit, Laurencetown, and the vicinity of Halifax, Lunenburgh and Wine Harbour; and arrangements were made by the Government for the allotment of mining areas, and for surveys of the district by Mr Campbell and Mr Poole."

The principal gold region of Nova Scotia is the long belt of partially metamorphosed rocks extending along the south coast from Yarmouth to Cape Canseau, and, on the grounds which I have stated above, believed to be of Lower Silurian age. The sedimentary rocks of this region, as already stated, are slates and quartzites,* usually in thick bands, and thrown into a great number of abrupt anticlinal and synclinal folds ranging in direction from N.E. and S.W. to nearly east and west; though, where the band becomes narrow eastward of the St Mary's River, it would seem that the whole of these beds are thrown off from one predominant anticlinal line. The gold occurs in veins of milky and translucent quartz, contained in the beds of quartzite and slate, and almost invariably running with the strike of the beds. It is associated with several other metallic minerals, to be mentioned in the sequel.

The veins range in thickness from a few inches to eight feet or more, and are not constant in thickness. This is a usual character of such deposits, and arises from their occupying irregular and often shifted or faulted spaces or openings in the beds. The dip of the larger veins usually coincides with that of the bedding, but not unfrequently crosses the slaty structure where this differs from the bedding. It results from this arrangement, that the actual relation of the veins to mining operations is rather that of beds than of veins, and that they dip away from the anticlinals in the same manner with the beds; one case being known where an auriferous quartz vein folds round the crown of an anticlinal arch. These peculiar characteristics of the auriferous veins will be illustrated in the sequel. It is not easy from mere inspection of the vein-stone to predicate as to its value, since the gold is usually invisible to the eye. It is found, however, that the milky white and colourless varieties of quartz are the least rich, while that which has a gray or leaden colour, and is associated with metallic sulphurets, which in their decomposition cause it to become stained, is the most productive.

* The quartzite or bedded quartz rock is locally known under the name of "whin."

I had an opportunity, in 1866, of examining one of the mo extensively worked deposits in Nova Scotia, that of Waverle near Halifax, in company with my friend, James Thomson, Esq., Halifax, and shall describe it as a characteristic example of t whole. This district is situated in the vicinity of Lake Thoma about ten miles distant from Halifax. The ore is extracted fro a number of openings along the strike of the vein, worked by hor gins. The deepest pit was 225 feet, on the slope of the vei On descending this pit, I found the vein to consist of compa grayish-white quartz, varying in thickness from four feet to s inches, but having an ordinary width of about two feet. Its stril is S. 50° W. magnetic, and its dip at an angle of 65° to 70° to t north-west. The lower wall, where I saw it, consists of coar gray slate, with small cross veins of quartz. The upper wall hard gray quartzite presenting a waved and crumpled surface, whi I have no doubt is an original strata plane, and shows that the ve is strictly in the plane of the bedding (Fig. 218). The quar

Fig. 218.—*Bottom of a Shaft in the Waverley Gold Mine.*

of the vein itself has a laminated or banded appearance, and t gold seems to be most abundant near the walls; though visible go is rare in this vein at present, the greater part being in a minute disseminated and invisible state. The superintendent of one of t mines informed me that the thicker portions of the vein afford scarcely more gold than the thinner portions, and that the go is most abundant near the hanging wall. This vein is known as t Tudor vein, and two smaller veins occur in its vicinity. O

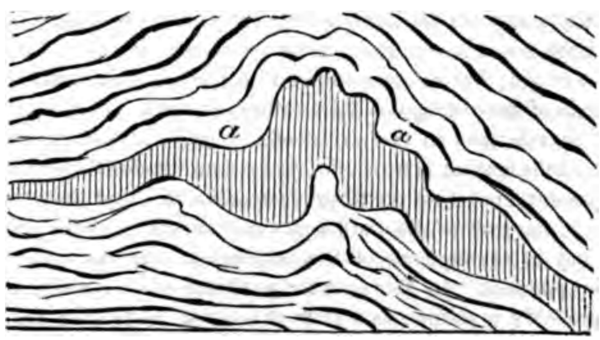
is ten feet to the north of the Tudor "lode" or "lead," the othe is 1100 feet to the south. Their course appears to be similar to tha of the principal lode.

The quartz from the workings of the "German Mine" at Waverley is crushed in an admirable stamping mill, worked by steam, and at present having sixteen stamps, though capable of being increased to more than double that number. The apparatus for the subsequent amalgamation and distillation necessary to obtain the gold appears to be of a very complete character, though improvements are still being made, more especially in the processes for obtaining gold from the metallic sulphurets. There are three other mining properties in the vicinity, and in the line of the same veins, but in these the mining operations are less considerable. The yield of the Waverley mines in 1865 was 13,102 ounces. The number of men employed was 270. Five mills were in operation; four worked by steam and one by water. The yield of gold was rather more than an ounce for each ton of quartz crushed, and the rate of return per man was $895 per annum. In 1866 the yield per man was only $584. This Waverley district was until lately the most important gold-producing area in Nova Scotia.

On one of the claims on the Waverley area a remarkable undulation of the containing beds has affected one of the gold-bearing veins in such a way as to produce the appearance known as "barrel quartz," and which has been described by Professor Silliman, Dr Honeyman, and others. When first uncovered, the quartz vein at this place presented the appearance of a series of arches parallel to each other, and resembling trunks of trees placed horizontally side by side. At the time of my visit these barrels had been removed, but a more simple continuation of the structure could be seen in a shallow adit which was being worked in the course of the vein (Fig. 219), and also in some open excavations. The appearances showed that the barrel arrangement had constituted the crumpled crown of an anticlinal bend or arch—an explanation already given by Professor Silliman, and on one side the vein could be seen following the beds downward on the side of this arch. The arrangement indicates great lateral pressure; and, which is of more importance, proves conclusively that the quartz veins are contemporaneous with the folding of the rock, since they have perfectly followed its folds without fracture. That the auriferous quartz veins are not beds, is evident from the manner in which they send off branches into the neighbouring rock, as well as from their own crystalline structure and the character of the imbedded minerals. They are undoubtedly true veins, but not veins formed by fracture of

the containing rocks when in a hard and metamorphosed state. They have been formed and filled in the very act of the contortion and altering of the strata, and are thus of the nature of segregation veins, gradually formed as the spaces containing them were opened out, by a process so slow and gentle that the containing beds were bent without fracture and with but little crushing. The barrel quartz is most instructive as an illustration of this peculiar mode of formation, which must have often occurred in the disturbance and metamorphism of sediments; though geologists, from the habit of looking exclusively at fissure veins on the one hand, and beds on the other, have often been puzzled by these apparent anomalies which occur in the case of what may be termed contemporaneous veins following the strike of the enclosing beds, and which, while simulating beds, and obviously not filling mere rents or fractures opened in hard rocks, must have been produced by forces acting long after the original deposition of the containing strata.

Fig. 219.—*Section of Vein of "Barrel Quartz," Waverley.*



(*a*, *a*) Quartz vein, with contorted slate below and quartzite above.

The minerals associated with the gold at the Waverley Mines are mispeckel (sulph-arsenide of iron), galena (sulphide of lead), blende (sulphide of zinc), and, more rarely, iron pyrites, copper pyrites, and calcareous spar. The visible gold appears in irregular grains and nuggets, included in and attached to the mispeckel, galena, blende and quartz, in such a manner as to show that it is in all cases either of contemporaneous or later introduction, and it has probably been segregated from the mass of the quartz when the latter was in a soft or pasty condition, or while it was in process of deposition. This view is confirmed by the fact, that those veins and parts of veins, which contain many "sights" or visible portions of gold, are less rich in

disseminated gold than those which are deficient in visible gold. Some of the richest veins indeed rarely show visible gold, while others which contain nuggets are in other respects very poor. A specimen of calcareous spar from the Waverley vein, given to me by the superintendent, seemed to be of later formation than the quartz, and to have filled a "vug" or cavity; but in a specimen from the Britannia Mine, presented to me by Mr R. G. Fraser of Halifax, a magnesian and ferruginous calc-spar holding gold occurs near the wall of the vein, and is interlaced with thin veinlets of quartz which are highly auriferous. Gold also occurs occasionally in the slate forming the wall of the vein, occupying minute crevices in the rock, and I observed at the Montagu Mine, near the Waverley, that gold occurs in thin veins of quartz and mispeckel, penetrating the slate to some distance from the main vein. At the Montagu Mine the vein worked is from four to eight inches thick, and is enclosed in gray slate nearly vertical, and with strike W. 5° S. to W. 10° S. Another smaller vein occurs at a distance of fifteen feet; and about five feet from this last the slate gives place to quartzite, which in this vicinity appears to alternate frequently with the slate.

No geologist who examines these veins can, I think, doubt their aqueous origin; but different opinions may be entertained as to the precise mode of introduction of the metallic minerals. The facts already stated, in reference to the structure and mode of occurrence of the veins, and the manner in which the gold is associated with the other minerals present, appear to me to prove conclusively that the veins were formed at the time of the disturbance and alteration of the containing beds, and in consequence of the mechanical and chemical changes then in progress. In this case the gold and other metallic minerals were probably contained in a state of solution in alkaline sulphurets, in the silica-bearing heated waters which penetrated the whole of the beds, and from which, as from a sponge, these silicious and metallic matters have been pressed out in the folding and contortion of the beds. In Nova Scotia it appears that those changes by which the older sediments have been brought into their present state occurred in the latter part of the Devonian period, as I have pointed out in my paper on these rocks in the "Canadian Naturalist and Geologist" already referred to, and in a previous chapter of this work. Accordingly, in one of the gold districts of Nova Scotia, as already explained,* nuggets and grains of gold are found in the Lower Carboniferous conglomerate associated with debris of the quartzose and slaty matrix. This interesting example, first noticed by Mr Hartt, proves that the gold veins

* See above, under "Carboniferous," p. 277, ante.

were in their present state at the time when this old gravel of the Lower Carboniferous period was being formed.

To sum up our conclusions on this subject:—The rocks containing the auriferous veins of Nova Scotia are of Lower Silurian age. The veins themselves were opened out and filled with the minerals which they now hold at the time when these Lower Silurian rocks were contorted and altered, and this probably occurred in the Devonian period, contemporaneously with the production of intrusive granites, and in connexion with the changes of metamorphism then proceeding. It was certainly completed before the beginning of the Carboniferous period, since which time little change seems to have occurred in the veins.

The "Gold Districts" at present recognised by the Government of Nova Scotia are,—*1st*, The Ovens and Gold River, in Lunenburgh County; *2d*, Renfrew and Mount Uniacke, Hants County; *3d*, Oldham, Waverley, Montagu, Laurencetown, and Tangier in Halifax County; *4th*, Wine Harbour, Sherbrooke, and Stormont, in Guysborough County; and, *5th*, Middle River or Wagamatcook, Victoria County. All of these, except possibly the last mentioned, and the opening in the Lower Carboniferous conglomerate at Gay's River already mentioned, are in Lower Silurian rocks.

In all parts of this district, the conditions under which the precious metal occurs in the rocks are similar to those above described; but at the "Ovens" in Londonderry County we have the remarkable, and, in so far as I am aware, unique spectacle of a modern gold alluvium now actually in process of formation under the denuding action of the waves. The slaty rocks of this coast holding auriferous quartz veins are daily being cut away by the waves of the Atlantic, and the gold is accumulating in the bottom of the shingle produced, and in the crevices of the subjacent rock. The portion of this deposit available at present is only that on the beach; but there can be no doubt that if the bed of the sea were elevated into land, the alluvia exposed would be precisely similar to those of California or Australia. We have thus in Nova Scotia marine gold alluvia of Lower Carboniferous and of modern date, and there are no doubt others of intermediate ages; but their amount, in so far as yet ascertained, does not seem to be great, and the chief supply of gold is likely to be derived, as at present, from the original repositories in the quartz veins.

The annual yield of gold from the Nova Scotia Mines is stated in the Report for 1865 to be 24,867 ounces; that for 1866 is 24,162, that for 1867, 27,583 ounces. These amounts cannot, however, be considered as approaching to the possible productiveness of these

mines in the future. The total area of the gold region may be estimated at about 7000 square miles, and the proclaimed districts do not yet reach a twentieth part of this area. Discoveries are being continually made; but in a country covered with wood and with boulder clay these must be slow and gradual in their progress. The quartz veins, which run in the strike of the beds, seem everywhere to contain gold, and the rocks throughout the whole area, are interlaced with such veins, few of which have been exposed, and of these few have yet been tested. It may therefore be anticipated that the productive gold districts will for some time continue to enlarge and increase in value, and that occasionally a strong stimulus will be given to enterprise by great and unexpected discoveries.

It is also to be observed that the veins at present opened are not yet worked up to their highest point of profit. Even in the larger mines, like those of Waverley, no vertical shafts have been sunk on the vein, nor have the excavations been extended beyond a very moderate depth. The desire to make the work remunerative as it proceeds has induced all the Companies to sink on the slope of the veins, and to conduct the works on the cheapest possible plan. I am convinced, however, from a consideration of the regularity and extent of the veins, that were vertical shafts sunk to a great depth, and regular mining on the Cornish plan pursued, the preliminary outlay would be more than repaid by the increased production. At the depths to which excavations have been carried some of the veins have improved; others appear to have diminished in productiveness; but there is no reason, except the analogy of certain other gold regions, and this is often a very fallacious guide, to doubt that the principal veins opened continue productive to great depths, and that by opening them extensively richer portions might be found to compensate for the poor ground sometimes reached in the present workings. It would, I think, repay the provincial Government to give special privileges to Companies which would expend sufficient capital to open mines on a large scale.

In 1855, I supposed that the probabilities of the occurrence of gold in the inland hills of Upper Silurian age were even greater than those in the older rocks of the coast. This view was based on the then received age of the Canadian auriferous deposits, and on the apparently more metalliferous character of the inland rocks. Experience, however, has hitherto been in favour of the coast series. Gold has, it is true, been found in the inland district, and possibly in the Upper Silurian series. The Middle River district in Cape Breton may be of this age. Gold has been found in the vicinity of Cape Porcupine,

and in a recent paper by Mr P. S. Hamilton, I find the statement that it has been found near the head waters of the Musquodoboit and Stewiacke Rivers, and also near Five Islands. The same authority also states that gold has been found in quartz occurring in the Triassic Trap of Partridge Island and Cape D'Or. In this last case the metal has possibly been brought up by means of the Trap from its original repositories in the Silurian rocks below. These facts indicate that though the coast series is at present much more productive, important discoveries may yet be made in those rocks of Upper Silurian age which constitute the inland metamorphic hills extending from Annapolis County to the North of Cape Breton, and also constituting the Cobequid range. On the view of the origin of the veins given above, there is no reason why the Upper Silurian series should not be auriferous as well as the Lower; and it is known that gold occurs in both series in the gold district of the province of Quebec, and perhaps more abundantly in the Lower Silurian.

The large areas of altered Lower and Upper Silurian rocks, indicated in the map as occurring in New Brunswick, are also likely to afford gold, more especially as a portion of this area in Northern New Brunswick may be regarded as a continuation of the gold district of Lower Canada. Nor are the metamorphic rocks of the southern part of New Brunswick unlikely to afford the precious metal, more especially those of Lower Silurian age; and recent discoveries in Canada show that this probability may extend even to the still older Laurentian series.

It has been remarked, that it is wonderful that in a district so thickly settled, and so much subjected to the operations of the surveyor, road-maker, and agriculturist, as the south coast of Nova Scotia, so numerous deposits of gold should so long have escaped observation. Geologists also and mineral explorers have repeatedly visited and passed through the district. Still, when it is considered that the country is netted with quartz veins, and that perhaps not more than one in a million of these is appreciably auriferous, the wonder ceases. Ordinary observers do not notice such things. A geologist, not specially looking for useful minerals, soon becomes wearied of breaking up and examining barren veins of white quartz, and certainly cannot spend two years in "prospecting," as the discoverer of the Wine Harbour deposit is said to have done. My own field notes contain the record of many days of hard work among these unpromising rocks, and countless quartz veins have suffered from my hammer without yielding a speck of gold. I believe I have visited

all the localities of the discoveries except Tangier, and in some of them, as at the St Mary's River, Indian Harbour, and Wine Harbour, I have spent days in examining the rocks, not certainly with a special view to the discovery of gold, but often with the assistance of intelligent friends who were good observers. The truth is, that in cases of this kind it is difficult to make the initial discovery; but this once made, it is comparatively easy to trace the productive rocks over considerable districts, if the requisite knowledge of the geological character of these has been obtained.

The conditions under which gold occurs in Nova Scotia are quite similar to those of other auriferous regions. The principal point of difference is the amount of gold found in rock veins, as compared with alluvial washings derived from their waste—a mere accident of the deposits or of the mode of exploration. It is probable that the Nova Scotia deposits are strictly a continuation of those which run along the eastern Appalachian slope as far as Alabama, and which may throughout, as in Canada and the Ural Mountains, occur in altered members of the Silurian series. It is to be anticipated that the connexion with the auriferous deposits of the United States may soon be effected by the discovery of gold in the metamorphic districts of New Brunswick. The quartz veins of Nova Scotia are remarkably rich in gold; and, as already stated, there is no reason that they will be found to diminish in productiveness in following them downward.

There is little room to doubt that gold will be found throughout the coast metamorphic district of Nova Scotia: more especially the slaty rocks of southern Guysborough, Halifax, Lunenburgh, and the northern parts of Queen's, Shelburne, and Yarmouth, may be expected to be auriferous. Careful examination may show that the gold occurs chiefly or entirely in the veins traversing certain bands of the thick beds of slate and quartz rock in these districts; and these may be recognised by their mineral character, especially if defined in their relation to the other beds by a detailed survey of the productive localities. Still the indications in one locality may not be unfailing when applied to another; and in the meantime it would be the best course for explorers to look at all quartz veins, and especially at those occurring in soft dark slaty beds, particularly near the junction of these beds with other rocks. Further, it would seem that the narrower veins, those following the strike of the rocks, and those stained with iron rust, are most likely to be productive. Minute examination should be made, as gold often occurs in a very fine state of division, though sufficiently abundant to pay for extraction. Nor should the

washing of the sands and gravels in the beds of rivers, and of the alluvial deposits on their banks be neglected, for it may happen in many cases that gold may occur in these when the veins originally containing it have had their outcrops worn away or concealed. Exploring for gold in new localities cannot be expected to be remunerative, except in rare cases; but it would be well at least that persons residing in the district above referred to, would embrace such opportunities as may occur of examining the quartz veins in their vicinity. It is to be hoped that in a short time a geological survey will place within their reach greater facilities than those which now exist, for making discoveries, and improving those already made.

The table on the next page, from the Reports of the Commissioner of Mines for 1866 and 1867, will give more precise information as to the present state of gold production in Nova Scotia, and the following remarks relate to districts not mentioned in the table :—

The Ovens in Lunenburgh County yielded, in 1862, 361 oz. of gold from surface washings. The mine at Laurencetown yielded in 1862 75 oz., and that at County Harbour 40 oz., but operations have been suspended at these places. Mount Uniacke is a new locality recently opened, and yielded in 1867, 947 ounces of gold. Localities in Upper Stewiacke, Musquodoboit, and Sheet Harbour, are also attracting attention.

The "Chester Mining Company" have opened shafts on some of their gold veins on Gold River, which are said to be very promising; one sample tested having given 77 dwt. gold, and 12 oz. silver per ton. Alluvial sand from the banks of Gold River is said to have afforded to Professor How gold at the rate of 14 dwt. 10 grains to the ton. This last fact is of some interest as indicating the possible occurrence of auriferous alluvia which seem to be rare in Nova Scotia; but perhaps might reward more careful search, more especially in the *lower part* of the boulder clay, and in the bottom of the beds of more recent alluvial sand and gravel. Even poor deposits of this kind might be made to pay by the methods of hydraulic washing on a large scale now in use in California.—

The mining of gold for the present eclipses all the other resources of this district of Nova Scotia. It is not known to contain any other metallic minerals of value. Its granite, however, affords an excellent building stone, now used to some extent, more especially in Halifax. Some of the bands of slate have been opened for roofing slates, but I believe not as yet on a large scale; and clays of excellent quality for bricks and coarse pottery occur at Chezzetcook and other places on the Atlantic coast, and are manufactured to some extent.

Statement showing the average daily labour employed, the amount of Quartz crushed, "the yield of Gold per ton of Quartz," the quantities of Gold from Alluvial Mines, the yield of Gold, the maximum yield per ton in each District and in the whole Province, and the value of the average yield of Gold per man employed in Mining for twelve months ending September 30, 1866, *with the totals for* 1867.

DISTRICTS.	Average men employed.	Crushing Mills employed, Sept. 30, 1866.	Steam power.	Water power.	Quartz, Sand, and Gravel crushed.	Yield per ton.	Gold from Alluvial Mines.	Total yield of Gold.	Maximum yield per ton.	Average yield per man for 12 months, at $18·50 per oz.
Stormont, Isaac's Harbour	34½	3	2	1	1956 07	0 10 18	...	1055 07 13	3 00 00	$565 91
Wine Harbour . . .	35	4	3	1	2192 08	0 11 04	...	1224 13 01	87 00 00	647 27
Sherbrooke	69	4	4	...	2684 01	1 22 00	...	5157 14 17	16 06 16	1382 86
Tangier	28	4	1	3	956 02	0 08 19	11 17 04	420 00 03	4 18 00	277 50
Montagu	26¾	1	1	...	563 05	1 06 00	...	707 01 01	3 12 00	488 95
Waverley	332	7	6	1	17286 00	0 12 01	...	10486 00 21	3 07 00	584 31
Oldham	36	7	5	2	964 02	0 16 02	...	776 12 04	6 03 19	399 06
Renfrew	94	7	5	2	4181 07	0 19 23	...	4176 03 17	9 18 00	821 90
Unproclaimed and other districts . . .	12½	1	...	1	179 10	0 17 15	24 17 11	158 11 08	12 00 00	234 65
Totals	667¾	38	27	11	30963 02	0 15 14	36 14 15	24162 04 13	87 00 00	$669 41
Totals for 1867 .	676	35	27	8	30673 00	0 17 23	49 01 15	27583 06 09	26 13 08	$765 00

2. *Lower Silurian of the south shore of New Brunswick.—The Acadian group.*

The city of St John stands on the outcropping edges of a thick band of hard slaty rocks underlying the Devonian beds, which appear at the southern end of the city. These St John rocks were until recently of uncertain age. Believing them to underlie conformably the last-mentioned series, I had supposed them to be Lower Devonian or Upper Silurian, but Mr Matthew has ascertained that they are really unconformable to the overlying formation; and more recently the discovery of fossils by that gentleman and Mr Hartt in the lower part of the series has set the question at rest.

The general character of the formation is thus given by Mr Matthew:—"It consists of a gray clay slate often sandy, the layers of which present glistening surfaces, owing to the abundance of minute spangles of mica. This rock very frequently becomes very fine in lamination and texture, and dark in colour. Four thick bands of this kind occur, the uppermost of which is a black papyraceous shale. The three bands of coarser shale which alternate with them include numerous layers of a fine compact gray sandstone, from a few inches to ten feet or more in thickness; a few are so highly calcareous as to become almost limestones. The surfaces of the layers in the coarser beds are frequently covered with worm-burrows, ripple marks, shrinkage cracks or scratches—apparently made by creatures gliding through the shallow waters in which they were deposited, and other evidences indicating that the slates are in great part of littoral origin."

The following section of the series at St John is given by the same observer:—

	feet.	feet.
"1. *a.* Gray sandstone or quartzite	50	
b. Coarse gray arenaceous shale. [This and the preceding are passage-beds from the Coldbrook or Huronian group.]		
c. Gray argillaceous shale, rich in fossils: *Paradoxides*, *Orthis*, *Conocephalites*, *Obolella*.	150	
d. Black carbonaceous shale, full of fossils: *Paradoxides*, *Conocephalites*, *Orthis*, *Discina*, *Orthoceras*, and a thin subtriangular shell resembling *Theca*, all much distorted		200
2. *a.* Dark-gray shales, with thin seams of gray sandstone	220	
b. Coarser gray shales, with gray flagstones . . .	200	550
c. Gray sandstone and coarse shales: *Lingula*, etc., .	130	
3. *a.* Dark-gray shales, finely laminated	450	
b. Black carbonaceous and dark-gray argillaceous shales more compact than the last	300	750
4. Shales and flags resembling 2 *a* and *b*		800 (?)
Carry forward		2300

Brought forward		2300
5. Black carbonaceous shales, resembling 3 *b*, but finer and softer		450
6. *a.* Shales and flags like 2 *a* and *b*: *Lingula*, a Conchifer, Coprolites, Worm-burrows, and Crustacean markings	700 (?)	1100 (?)
b. Gray and ferruginous sandstones and beds of coarse shale: *Lingula*	400	
7. Black carbonaceous shales, finely laminated		650
		4500"

Westward of the St John River, the rocks of this series extend through Carlton, but soon diminish in thickness and disappear. To the eastward they are prolonged in a band skirting the older (supposed Huronian rocks) to Loch Lomond, where they disappear along the line of outcrop proceeding from St John, but reappear on the other side of a synclinal, and extend with opposite dips nine miles farther to the eastward. Their whole extension in this district is about thirty miles, with a breadth of about four miles. Farther details will be found in Professor Bailey's Report.

Though thus limited in their distribution, these beds are in the highest degree important in a geological point of view, as their fossils establish for the first time on the American Continent a series of fossiliferous beds older than the Potsdam sandstone, hitherto supposed by American geologists to be our oldest Palæozoic group; and corresponding with the older Lingula flags of Wales, and with Barrande's "Etage C." in Bohemia. These fossils also contribute to affix the same age to the *Paradoxides* slates of Newfoundland, and of Braintree, Massachussets. In other words, they add a new formation to the Palæozoic period in America. This formation has as yet been known as the St John group; but I think this name unsuitable, both on account of the number of places known as St John, and on account of the variety of formations occurring near St John in New Brunswick, and would therefore propose for the group now under consideration, characterized by *Paradoxides*, *Conocephalites*, etc., and the oldest known member of the Palæozoic of America, the name Acadian Group, by which I hope it will be known to geologists in whatever part of America it may be recognised.

In the northern part of New Brunswick a broad belt of metamorphic rocks with granite bands extends from the south shore of the Bay de Chaleur westward of Bathurst in a south-west direction to the sea-coast of Maine. These rocks were denominated "Cambrian" by Dr Gesner and Dr Robb, but by more recent observers are regarded as Lower Silurian, principally on the ground of difference in mineral character from the Huronian rocks and similarity to those of the

Lower Silurian as developed at St John and in Nova Scotia. The following remarks on their age are from a paper by Mr Matthew, already quoted:—

"A provincial collection in the University Museum of the rocks in this quarter closely resembles those of the Lower Silurian slates of St John, and differs essentially from the Upper Silurian and Devonian deposits which have been recognised in this region.

"In the alternations of arenaceous and dark-coloured clay slate with intercalated quartzite, this formation, which is also auriferous, resembles the gold-bearing series of the Atlantic coast of Nova Scotia, long ago recognised as Lower Silurian by Dr Dawson. If both prove to be on the same horizon geologically as the St John series, namely, the lower part of the Lower Silurian, our knowledge of the age and relations of the older metamorphic rocks of Acadia will be placed on a firmer basis than heretofore.

"So far as our knowledge goes, they differ from contemporaneous deposits to the westward in being conformable to the Huronian series; and also in the rarity of calcareous and magnesian sediments, there seeming to be little else than shales of various degrees of fineness, flagstones, and quartzites."

Professor Hind, in his Preliminary Report, regards these rocks as equivalent to the Quebec group, which is now recognised by the Canadian Survey as between the Calciferous and Chazy; but whether this is their real age, or that somewhat lower horizon which is marked by the fossils of the St John group, we have at present no certain means of determining. The rocks above referred to constitute two broad bands flanking a ridge or series of interrupted parallel ridges of granite, believed to be of Devonian age. In the maps of the Province these belts have usually been marked as uniform and regular, with an aggregate width of 35 to 50 miles, but Professor Bailey informs me that many facts known to him render it probable that their limits are more irregular and not well ascertained. I have marked them in the map as nearly as possible in accordance with the views of Professor Bailey and Professor Hind.

A shorter belt of mica schist and other metamorphic rocks associated with granite, which runs parallel to the south-eastern side of the New Brunswick Coal-field, and near the St John River, comes into contact with the supposed Upper Silurian belt of Kars and Havelock, is believed by Professor Bailey, on the evidence of mineral character, to be probably of Lower Silurian age. This belt, extending to the south-west, unites with the others above mentioned in the south-western corner of the province, the greater part of which is

believed to be occupied with altered Lower Silurian rocks; but the precise distribution of these, and the limits between them and the older and newer rocks in their vicinity, are very imperfectly known.

Useful Minerals of the Lower Silurian of New Brunswick.

Gold.—The probability that these rocks in New Brunswick may be geologically equivalent to the auriferous rocks of Nova Scotia and of the province of Quebec, would of itself excite hope that the precious metal might occur in them. In addition to this, drift gold has, according to Professor Bailey, been found on the head waters of the Tobique and Miramichi, and at the Grand Falls of the St John, and it has also been found *in situ* by the officers of the Geological Survey of Maine at St Stephens. At this place it occurs in quartz veins in micaceous schist. Professor Hind also states that gold has been found in a "black plumbaginous slate" at St Stephen. These indications are sufficient to warrant the hope that important discoveries would reward a careful exploration of this district.

Antimony.—This metal was discovered to exist in the parish of Prince William, York County, about twenty-five miles from Fredericton in 1863, and subsequent exploration has led to the belief of the existence of very important deposits. The ore is a pure sulphuret, capable of yielding about 70 per cent. of metallic antimony, and is contained in numerous large and well-defined veins of quartz, filling lines of dislocation in highly tilted argillaceous slates and quartzites. "These veins are true veins of segregation, showing a distinctly banded character, and an alternation of materials, the antimony ore itself frequently forming distinct layers, though often penetrating irregularly the surrounding rocks. Excavations have been made by different Companies at several points, two of them distant more than three-fourths of a mile from each other, and have in each case proved productive. No very persistent or vigorous operations have, however, as yet been carried on. 533 cwt. of ore was exported in 1864."*

Small quantities of silver occur in the antimony ores of this place.

Lead.—Indications of galena or sulphuret of lead are reported as having been found on the Tobique and elsewhere; but, as yet, nothing remunerative.

Copper.—In Professor Hind's Report, a number of localities of copper ores are mentioned; but as in all of them the metal appears

* Professor Bailey, MS.

to be, so far as at present known, in very small quantity, I merely refer to his Report.

Iron.—The most important deposit at present worked in this district is that at Woodstock. At this place the ores, according to Professor Hind, are in "sedimentary deposits many feet in thickness, interstratified with red and green argillites or with calcareo-magnesian slates of a red and green, or mottled red and green colour. The ores vary in composition, being both red and black. The black is sometimes feebly magnetic, but it derives its colour more from the presence of manganese than from the black magnetic oxide."

One or more furnaces are in constant operation at Woodstock, and others are in process of erection. The iron is of a superior quality. The ore yields 32 per cent. The quantity produced in 1864 was 2750 tons.

Manganese occurs in the Tattagouche River, and has been worked to a small extent.

Nickel, in the form of green silicate, is found in small quantities associated with the antimony ore of Prince William.

Zinc, in the state of blende or sulphuret of zinc, also occurs in small quantity in Prince William.*

Fossils of the Primordial or Acadian Group at St John.

These are the oldest organic remains which I can present to the reader from the rocks of New Brunswick or Nova Scotia, and they represent the oldest forms of life known to geologists, with the exception of the far more ancient *Eozoon Canadense*, and the few other organisms found with it in the Laurentian rocks of Canada. These fossils were originally discovered at Coldbrook by Mr Matthew, and they were subsequently collected by Professor Bailey, Mr Matthew, and Mr Hartt, at Ratcliffe's Millstream and also near the city of St John. The first publication in reference to them was the following notice by Mr Hartt in Professor Bailey's "Observations on the Geology of New Brunswick," 1865.

"My examination of the fossils collected last August, from the St John group, at Ratcliffe's Millstream, by Professor Bailey, Mr George Matthew, and myself, and of a collection made from the same group at Coldbrook, in 1863, by Messrs George and C. R. Matthew, is not yet sufficiently complete to enable me to give an extended description of them here. I shall therefore limit myself at present to a notice

* For the information under the above heading, I am indebted to Professor Hind's Report and the MS. notes communicated by Professor Bailey.

of the genera, and of the aid they afford in the determination of the geological position of the St John group, leaving the descriptions and figures of the species to be given in a future paper.

"The fossils as yet known to occur in the rocks of the St John group, are principally Trilobites, which are represented by quite a large number of species, and Brachiopoda, which last are of more rare occurrence. All these fossils are preserved as casts or impressions, the tests of the crustacea and the shells of the Brachiopoda being usually transformed into oxide of iron.

"All the specimens have suffered more or less from distortion through pressure and the metamorphosis to which the rocks enclosing them have been subjected. The Trilobites occur also as detached fragments, so that their accurate determination is not easy, and more material is required in order satisfactorily to figure and describe all the species.

"Representatives of four genera of Trilobites have been obtained thus far from the St John rocks, viz.:—*Paradoxides*, *Conocephalites* *Agnostus*, and *a new genus* (?) allied to *Conocephalites*.

"The number of species in each genus has not yet been satisfactorily made out; but of *Paradoxides* there are at least five, of *Conocephalites* seven, and of *Agnostus* and the *new genus* each one.

"All the species appear to be new. One of the *Paradoxides* bears a close resemblance to *P. rugulosus*, Corda, from the *Etage C.* of Barrande, in Bohemia, and one of the *Conocephalites* is allied to *C. coronatus*, Barrande, from the same fauna and horizon, though neither is identical with the European species.

"There are six species of Brachiopoda, belonging to the genera *Orthis*, *Discina*, *Obolella*, and *Lingula*. I have not been able to identify any of the forms with described species.

"Though all the species from the St John group are apparently new, yet the occurrence of *Paradoxides* and *Conocephalites*, genera confined entirely to the so-called *Primordial fauna* of Barrande, and everywhere characteristic of it, together with the strong likeness borne by the St John species, in their facies, to those of the same genera of the faunæ of the "Primordial" in Europe and America, enable us unhesitatingly to assign to the St John group, or at least to that lower part of it which has afforded Trilobites, a geological position equivalent to Barrande's Etage C. or to the Lower Potsdam of America.

"Barrande uses the word *fauna*, in his term *primordial fauna*, in a sense equivalent to *epoch* or *horizon*. A fauna is strictly a collection of animals confined within a limited geographical area. The terms "primordial fauna," "second fauna," are used with propriety when applied to the groups of fossils characterizing the

Etages C. and D. in Bohemia; but these terms, unless limited, should not be extended to equivalent groups of the same age, but forming distinct faunæ, in other parts of the world, for such a *double emploi* is incompatible with that precision which should mark the use of scientific terms. Primordial *zone* is objectionable. If the term Primordial is used, and it is very appropriate, it would be much better to say Primordial *period*,—period, as used by Agassiz, being equivalent to Barrande's *étage*.

"The lower part of the St John group, at Coldbrook, has been divided by Mr Matthew, on lithological grounds, into three bands, viz.:—

"No. 1. The lower or arenaceous band, with no determinable fossils, and constituting passage beds from the Coldbrook group.

"No. 2. Argillaceous shales, rich in fossils, *Paradoxides*, *Orthis*, *Conocephalites*, *Obolella*.

"No. 3. Carbonaceous shales, full of fossils, *Paradoxides*, *Conocephalites*, *Orthis*, *Discina*, etc., all much distorted.

"I have not observed No. 2, at Ratcliffe's Millstream. No. 3, at Coldbrook, corresponds exactly, in its fossil remains, to the bed at the Millstream, from which the Trilobites, etc., were obtained. Nearly, if not all the fossils I have seen from No. 2, at Coldbrook, are entirely distinct from those of No. 3 of the same locality and the Millstream; but more material is required to establish the claim of these two beds to be considered as being characterized by distinct successive faunæ. At all events, all the species from both beds are different from those elsewhere occurring, and for at least bed No. 3, we have in the vicinity of St John a distinct fauna of the Primordial period."

Other engagements have prevented Mr Hartt from fulfilling his intention of publishing detailed descriptions of the species. In compliance, however, with my desire to place these interesting forms before geologists in this work, he has kindly communicated to me his MS. notes; and I have extracted from these the following descriptions of several of the more common species, with notices of the others:*—

Fig. 220.

Eocystites.

Eocystites primaevus, Billings, Coll. Hartt (Fig. 220). The little plate with radiating sculpture, represented somewhat enlarged in the figure, is regarded by Mr Billings, to whom the specimens have been submitted, as indicating a new genus of Cystideans.

* Mr Hartt desires me to state his obligations to Professor Agassiz for the opportunity of comparing these fossils with specimens in the Museum of Comparative Zoology, Cambridge, U.S.

Fig. 221.

Lingula Matthewi.

Lingula Matthewi, Hartt, MS. (Fig. 221). Dorsal valve,—circular in outline or very slightly wider than long, extremely flat, the convexity being scarcely noticeable; shell very thin; on each side a segment such as would be cut off by a chord running from the umbo to the extremity of the transverse diameter, is slightly turned up on the margin.

Inside, a strong mesial ridge, rounded and of moderate width, runs from the umbo to a point a little beyond the middle of the shell; at the umbo this ridge bears a small nail-head-like process or swelling, and there are two minute and extremely short secondary ridges, originating from the head of the primary, and extending obliquely backwards. Inner surface marked with numerous indistinct and irregular concentric striæ; outer surface not visible.

I have found one perfect dorsal valve in a piece of slate sent me by Mr G. F. Matthew from Coldbrook.

Lingula, n. s., Hartt, MS. Differs from the above in being almost straight in front, broadly rounded at the sides and narrowed towards and pointed at the umbo. It was also larger, thicker, and more convex. Ratcliffe's Millstream, Hartt.

Obolella transversa, Hartt, MS. A very small, transversely oval species, from Coldbrook, St John.

Discina Acadica, Hartt, MS. (Fig. 222). Shell elliptical in outline; sides more or less straight. Conical, but very depressed. Apex apparently central. Surface marked with a number of deep concentric irregular sharp furrows, not always continuous, and often breaking up into smaller grooves; and all these seem at times to be impressed with lighter lines running nearly parallel with them. Of the large furrows, from nine to ten can usually be counted. The whole surface of the shell is marked with a great number of delicate raised lines radiating from the summit to the circumference, and just visible to the naked eye. Rather rare in the Trilobite shale at Ratcliffe's Mill. The shell appears to have been thin, and is probably much compressed vertically. Collected by N. B. Survey and J. W. Hartt.

Fig. 222.

Discina Acadica.

Orthis Billingsi, Hartt, MS. (Fig. 223). Shell subquadrate to semicircular, broader than long; greatest width at the hinge-line; moderately convex; greatest thickness at about the middle, depressed in front. Hinge-line straight. Dorsal valve semi-circular or subquadrate, depressed, with a shallow sinus running from the umbo to the front. Umbo not elevated above the hinge-area, which is

Fig. 223.

Orthis Billingsi.

very narrow, and marked by fine parallel longitudinal striæ. Hinge-plate bearing two slight incurved internal processes. Ventral valve more arched than the dorsal, with a narrow flat margin produced in the plane of the valve. Hinge-area triangular, concave, and marked with fine parallel lines. Umbo elevated above hinge-line about one-fourth of length of shell. Foramen triangular and of moderate size. Surface ornamented by about thirty prominent rounded radiating plicæ, increasing in width towards the margin, becoming less elevated and slightly curved toward the ears, crossed by a number of distinctly marked, concentric, squamose lines of growth, and numerous fine concentric striæ. The radiating plicæ increase by bifurcation, which takes place at about one-third the distance from the umbo to the margin. Rather common in the Trilobite shales, Ratcliffe's Millstream, and St John. Collected by N. B. Survey and J. W. Hartt. The figure does not show the fine concentric lines.

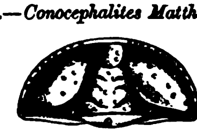
Orthis, n. s. There appears to be a second species in the St John slates; but the material at hand does not at present warrant its description.

Conocephalites Baileyi, Hartt. MS. Head transversely semi-elliptical, half as long as wide; anterior margin in front more or less straight, posterior margin quite straight; posterior angles of cheeks slightly rounded and unfurnished with spines. Facial suture never visible; anterior margin of shield with a narrow very elevated border, which is widest and most elevated in front, and grows narrower and lower posteriorly, becoming obsolete, or nearly so, at the posterior angle of the shield. This border is separated from the other part of the shield by a deep, rather wide furrow, which is deepest in front but grows shallower as the anterior border loses in height going posteriorly. General form of shield convex, but much depressed. Glabella more depressed than the cheek, sub-triangular, depressed convex, broadly rounded in front, and separated from the cheeks and front by a deep well-marked furrow; width at base equal to length, which last is about 7-10ths that of shield; very much narrowed in front. Lateral bounding furrows inclined to one another at such an angle as would cause them to meet if produced to the middle of the front margin of head. Occipital furrow deep and well marked, slightly arched forward in middle, and curving downwards and forwards, growing narrower at the extremities, and less deeply cut than the bounding furrow of the Glabella. No lateral glabellar furrows, or very slightly marked, never seen on casts. Occipital ring more elevated, and rather wider in the centre; bent forward at the sides; narrow, with a very low spine-like tubercle in the centre. Posterior furrow moderately

deep and wide. Sides of shield bent slightly downwards. Posterior angles flattened. Cheeks sub-triangular, bounded by the straight dorsal furrow, the straight groove which separates them from the glabella, and the curved marginal furrow. They are more convex or gibbous than the glabella, sloping gently towards the marginal furrow, but steeply to the other bounding grooves. In the cast they are marked on the edge of the bounding groove of the glabella at the points where the straight sides of the latter begin to curve around the front by two small, low, but well-marked ocular prominences, from each of which extends a slight ocular ridge, with a more or less outward curve towards the posterior angle of the shield, but usually losing itself at about half the distance in a system of delicate ramifications, which may often be traced to the posterior angles of the cheek lobes. Like ramifications are thrown off for the whole length of the ridge from its anterior side, and these occupy the surface of the cheek-lobes in front of the line. The surface of the cast sometimes appears granular, but the mould is always smooth, and the outer surface of the shield was unfurnished with tubercular or granular ornamentation. The posterior border on each side of glabella is very elevated in the middle, and loses height thence each way. Cephalic shield sometimes an inch and a half in width.

Heads only of this species have been found. They occur in moderate abundance in the primordial shales of the St John group at Ratcliffe's Millstream. Collectors, Professor L. W. Bailey, G. F. Matthew, J. W. Hartt, and C. Fred. Hartt.

Fig. 224.—*Conocephalites Matthewi*, head.*



Conocephalites Matthewi, Hartt, MS. (Fig. 224). Head, semicircular to semi-elliptical, more than twice as wide as long; front and lateral margins forming a regular curve; posterior margin nearly straight; posterior angles of shield flattened and rounded without spines; margin with a strong, round, rather narrow fold, which becomes narrower and lower towards the posterior angle of shield, where it disappears. This is separated from the cheek-lobes by a very deep, moderately broad groove. This groove is arched forward in front by a large semi-globose swelling, situated just in advance of

* Owing to the difficulty of drawing from imperfect and distorted specimens, this and the following figures do not adequately represent all the characters of the species as described by Mr Hartt.

the glabella, encroaching upon the marginal fold, causing it to be thickest on each side of this prominence.

The posterior margin is also folded, but the plait is more or less inclined backwards. The fold is narrow near the occipital ring, but grows more prominent, and gains in width towards the posterior angle, but, like the anterior fold, it disappears at that point. Its course is not straight; at about half the distance of the outer angle it bends slightly backwards and downwards, and then forwards slightly, to disappear on the flattened or rounded angle of the shield. This fold is separated from the cheek-lobes by a groove shallower and broader than the marginal one, which it resembles, by expanding gradually into the flattened space of the outer angle. This groove follows a course parallel to the fold which it accompanies. Length from occipital furrow about half that of head.

Glabella sub-conical, longer than wide, strongly rounded in front, and about half as wide anteriorly as posteriorly; length about half that of whole shield, strongly convex, but less elevated than the cheek-lobes, bounded laterally and anteriorly by deep grooves, the anterior being not so deep as the posterior. The sides of the glabella are impressed and divided into lobes by three pairs of deep lateral glabellar furrows. Those of the posterior pair are the longer and more deeply impressed. These furrows begin abruptly at a point somewhat in advance of the middle of the longer diameter of the glabella, and directed backwards at an angle of about 45° to the antero-posterior diameter of the shield, disappear abruptly without gaining the medial line, usually extending a little more than the third of the distance across the glabella. Those of the median pair begin also on the bounding groove very abruptly, only a little in advance of the posterior pair, but they are usually not so oblique, and extend on each side not more than a quarter of the distance across the glabella. The distance between the outer extremity of the median and anterior furrows is somewhat less than between those of the median and posterior, and these but slightly impress the sides of the glabella, and occasionally are scarcely visible. The anterior lobe is about as wide as the one which follows it.

The occipital furrow is deeply cut in the outer third of its length, and strongly directed forwards. In the middle third it is not so deep, and is quite strongly arched forwards. The occipital ring is narrow, strongly convex, and vertically arched, the sides being more or less narrowed, turned downwards and forwards, being projected obliquely more or less across the posterior marginal cheek-groove towards the inner posterior angle of cheek-lobe. The ring projects backwards beyond the margin, but not beyond the posterior lateral angle of shield. The

middle part is produced into a very short conical tubercle-like spine, directed slightly backwards. The cheek-lobes are strongly gibbous, and very regularly arched, the convexity being stronger anteriorly. A narrow distinct wavy ocular ridge begins on the cheek-lobe, just opposite the anterior part of glabella, and, thinning gradually out and arching, at first slightly forwards, curves round and is directed towards the outer angle of cheek-lobe, but it usually vanishes before reaching that point. From its anterior outer side it throws off a very numerous set of fine bifurcating raised lines or ridges. These lines are directed outward from the primary line at a rather acute angle, and appear to bifurcate several times. This ocular ridge is thickened at its commencement, but is not so strongly marked at that point as in *C. Baileyi.* It is also more arched forward than in the latter species. The whole outer surface of shield is covered by innumerable, close-set, raised points or granulations just visible to the naked eye, but very distinct under the lens, appearing in the impression of the shield as minute punctures. These appear to be more distinct on the convex portions of the shield. The raised margins, cheek-lobes, glabella, occipital ring, as well as the lobe just in advance of the glabella, bear sparsely sown, minute, short spines, which give to the surface a distinct granular appearance. These are always wanting in the furrows and on the cheek-lobes, are more crowded on the outer halves of the cheek-lobes. They are true spines, but usually appear as granulations on the casts.

In very young specimens, a line in diameter, the shield is semi-circular, the cheek-lobes are extremely gibbous, and very much more convex than the glabella, and the pre-glabellar lobe is very conspicuous.

I take great pleasure in dedicating this the most abundant and prettiest of these Trilobites to its discoverer and my intimate friend and geological companion, Mr G. F. Matthew. Common at Ratcliffe's and St John's. Specimens from Coldbrook show slight differences, probably only varietal.

Conocephalites Robbii, Hartt, MS. Head without movable cheeks, of moderate size, depressed convex, slightly arched in front, where the width is considerably less than behind. Length about equal to breadth in front.

Glabella, ovate-conical, sides straight, and dorsal furrows so inclined as to meet if produced in middle part of anterior margin; very convex; more elevated in the middle; posterior furrows reaching about one-third of the way across the glabella, directed strongly backwards, and reaching nearly to the base of glabella; middle furrows less distinctly marked, short, not so oblique as first; anterior very short, appearing only as little pits or depressions on the sides of the glabella.

Occipital ring narrow, convex, widest in the middle, narrowing towards sides, which are turned forward, giving to it a crescent shape. Occipital furrow deep and well developed, widest in the middle, where it slightly impresses the base of the glabella; narrow and slightly bent forward at the ends. The ring bears a little short conical tubercle-like spine in the middle, directed slightly backwards.

Fixed cheeks, frontal limb one-third to one-fourth of whole length of head, with a narrow, high, convex border, inside of which is a moderately deep furrow; cheek-lobes depressed, convex, meeting in front, rising abruptly from the deep dorsal furrow, on the borders of which they reach their greatest elevation, which, however, is not equal to that of glabella, and sloping thence roundly towards the sides and front. The posterior limb bears a deep, wide, furrow, which widens somewhat near extremity. The marginal fold is very narrow and of little prominence; and widens a little in the outer half. The posterior margin bends slightly backwards at extremity of limb, which is rounded. Ratcliffe's Millstream.—N. B. Survey and J. W. Hartt.

Conocephalites Orestes, Hartt, MS. (Fig. 225). The head-shield of this species without movable cheeks is of medium size, length about equal to breadth in front, or to two-thirds width behind; margin arched moderately in front, with a rather wide, low border fold, widest in front, narrowing toward the sides, separated from the rest of the head by a shallow groove. Glabella long, ovate, conical, or cylindrico-conical, extremely convex, wider behind than in front, where it is rounded. The sides are straight, and so inclined to one another as to meet, if produced, at a distance in advance of margin in front about equal to the distance of that line from glabella. The glabella is flattened on the sides, and never regularly convex.

Fig. 225.

Conocephalites Orestes, head.

There are three pairs of furrows, which lightly impress the sides of the glabella, and of which traces are not always distinctly preserved; and they are apt to be seen best in slightly distorted specimens. Dorsal furrow narrow, deep, and sharply cut; occipital ring widest in the middle, narrowed from behind at the sides, separated from glabella by a distinct furrow. Bears in the middle a minute tubercular spine pointing upwards. Fixed cheeks strongly convex, but much less so than the glabella, meeting in front with abrupt slopes toward dorsal and posterior marginal furrows, but with gentle rounded slopes toward sides and anterior groove. Ocular ridges, marked as lightly raised lines, originating at the dorsal furrow some distance behind

the front of the glabella, and rising obliquely upwards and backwards to ocular lobes, which are small and semi-lunar, folded considerably upwards, and are situated just opposite middle of head; width between ocular lobes about equal to width in front. Behind the eye the suture describes a long open sigmoid curve, which is continued inward somewhat so as to give the limb a rounded outline, and make the cheek here about one-third wider than at the eye. Posterior margin of cheeks with a slight fold, more prominent in the middle; outer half of this margin is arched backwards. Whole head arched slightly forward vertically.

This species resembles *C. Hallii*, Hartt, but differs from it in the shape of the anterior marginal furrow. This same feature and the long and narrow glabella distinguish it from *C. Robbii*. Rather common in shales at Ratcliffe's Millstream.—N. B. Survey, 1864, and J. W. Hartt.

Conocephalites elegans, Hartt, MS., Ratcliffe's Millstream. Head or cephalic shield semi-circular or semi-elliptical, more than twice as broad as long, nearly straight behind; anterior border with a very strong fold, separated from the rest of the head by a deep groove. This fold is widest and most elevated just in front of the glabella, where it is sometimes the tenth of an inch in width. At this point the groove bends abruptly and angularly, and arches forward on each side so as to encroach on the marginal fold and cause it to disappear at about half the distance between the middle point in front and the posterior angles of shield. The posterior marginal folds are very thin, most elevated in the middle, and sloping each way towards the occipital ring and posterior angles of shield. The axis of the outward half is more and more inclined backward from the perpendicular towards the posterior angles, which are rounded, more or less flattened, and without backward projecting spines. The grooves separating the posterior fold from the cheeks are very deep, and are slightly directed forward. Length of glabella about six-tenths of antero-posterior diameter of shield, a little wider at base than long, and less than half as wide anteriorly; triangular, with anterior part rather broadly rounded, highly inflated, and bounded by deep grooves, which in front join in with the anterior marginal groove. There are three pairs of glabella furrows. Those of the posterior pair impress deeply the sides of the glabella, are strongly curved backwards, and scarcely reach a third of the distance across each side. The second and third pairs only just impress in like manner the sides of the glabella. Those of the second pair are curved backward, and extend about a quarter of the distance across the glabella. Those of the third pair are very

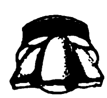
short, and appear to be parallel with the transverse diameter, but they are not always distinct.

Occipital furrow deep, slightly arched forward in the middle, and with the ends turned in the same direction; occipital ring of moderate width, the middle is produced into a spine often more than a quarter of an inch in length. This spine is more or less strongly directed backwards. The cheek-lobes are very gibbous, more so than the glabella. Their posterior border is so strongly impressed by the posterior furrow that it arches slightly over it. The surface of the convex part of the shield is ornamented by very fine, close-set granulations, distinctly visible to the naked eye, and by a set of delicate little tubercles more sparsely sown.

Rather uncommon at Ratcliffe's Millstream.—J. W. Hartt, Prof. Bailey, Mr Matthew, C. F. Hartt, and N. B. Survey, 1864. This bears in its granulated surface a strong likeness to *C. Matthewi*, but is distinguished from that species by the thickened, triangular, anterior border, the wider glabella less deeply lobed, and by the long occipital spine. The fine granulations are more distinct, while the coarser are tubercles and not spines. It is larger than *C. Matthewi*. Specimens without anterior border, and with badly preserved surface markings, are apt to be taken at first sight for *C. Baileyi*. The glabellæ of these two species are very alike in outline, but *C. Baileyi* wants the glabella furrows, or has them only indistinctly marked.

Conocephalites Ouangondianus, Hartt, MS. Head, without movable cheeks, strongly convex in outline, somewhat sub-angular in front; much narrower in front than behind, where width is greater than the length; width in front very nearly equal to length; anterior margin wide, with a strong fold, whose axis is strongly inclined forwards, so that it presents a short, steep, convex slope forward, and a long concave slope in the inner side, being much less elevated than glabella or fixed cheeks.

Fig. 226.



Conocephalites Ouangondianus.

Glabella long, ovate-conical, nearly twice as wide posteriorly as in front, very convex, slightly sub-angular at the middle; sides straight, inclined to one another so as to meet in the middle of front margin if produced; rounded in front. Casts sometimes showing three pairs of short, raised, transverse lines on the sides of glabella, occupying the position of the ordinary glabella furrows; of these the two posterior are directed obliquely backwards. In some specimens there seems to be a fourth pair in advance of the other, represented by little tubercle-like processes, situated on the side of the glabella in front, just where the sides curve to the front. Glabella very much more convex than fixed cheek.

Occipital ring strongly arched upward, and separated from glabella by a well-marked groove; middle of posterior margin produced backwards in a short conical spine. Fixed cheeks highest along dorsal furrow, towards which they pressed abrupt round slopes, while their general surface slopes gently and quite evenly towards front or sutures. The dorsal furrows are confluent in front with the flat margin, so that the cheek lobes do not meet in front. They are highest along the straight dorsal furrows, but where they bend to go round the anterior extremity of glabella, the cheek-lobes narrowing and curving towards each other, gradually sink away and disappear in the front flattened space.

The ocular lobes are very well developed, forming sub-semicircular lappet-like lobes, curved strongly upwards, and situated about opposite to the centre of the head. An ocular ridge, low and rounded, but very prominent, runs from anterior margin of ocular lobes, with a curve almost parallel with front margin of shield, but slightly divergent from it to the dorsal furrow, which it gains at a point considerably back of front of glabella, and where the straight part of the dorsal furrow bends to go round the front. Posterior limb short and broadly rounded. Post-marginal furrows less deep than dorsal, wider; marginal fold narrow and moderately prominent; shield strongly arched transversely; surface smooth.

Cephalic shields without fixed cheeks, only part preserved. Rather uncommon in the Trilobite shales of Ratcliffe's Millstream.—N. B. Survey, 1864, and J. W. Hartt.

Conocephalites tener, Hartt, MS. Minute, glabella ovate-conical, truncate at base, rounded in front, where it is about half as wide as at occipital furrow; slightly contracted behind; length about equal to width at occipital furrow; strongly depressed convex, more elevated at base than at front, and higher also than fixed cheeks; aspect varies with state of preservation of specimens; arcuate, rounded, convex, or concave; the middle seems to be inclined to project back slightly over the occipital furrow; slopes abruptly to occipital furrow, which is moderately deep, wide, and narrowed, and slightly inclined forward at the ends, where it terminates abruptly; bounding groove deeper than other grooves in head; occipital ring projecting backward bodily beyond higher margin, with the axis of its fold inclined more or less backward, and produced in the middle into a short conical backward inclined spine; anterior limb regularly arched as if the outlines of the complete head were semi-circular.

Fixed cheeks anterior border broad, flat-concave, rising more or less abruptly to a sharp, thin, marginal fold; width between anterior

extremities of cheek sutures equal to or about twice width of glabella at base. Cheek-lobes but slightly convex, and much more depressed than the glabella. Ocular ridges very distinct, thin, sharp, elevated ridges, that begin about inner edge of cheek-lobes, just behind rounded front of glabella, run outward and backward at an angle of 60°—65° to the antero-posterior diameter. They are at first straight, but soon begin to bend backward more and more abruptly, forming a fragment of a spiral, their extremities being slightly directed inwards. The width between the ocular lobes is about equal to twice the length of the glabella. The ocular ridges are inclined outwards and forwards. Another ridge of the same appearance begins a very short distance behind the origin of the former, and on the very margin of the cheek-lobes, and, diverging from the margin nearly opposite to the base of the glabella, bends off abruptly along the posterior margin of the cheek-lobe, describing a curve, whose convexity is directed backwards. This ridge terminates considerably outside of the ocular lobe at a point distant from the glabella about equal to half the width of the latter at its base. This ridge is usually found inclined in the opposite direction to the former, viz., inward and backward. Posterior margin of fixed cheeks moderately and regularly S-curved, the inner halves curving forwards, the outer halves backwards, with a marginal fold most elevated in the middle, but much less so than the ridges of the cheek-lobe or the anterior fold. This fold becomes double at about the middle, by the appearance of a groove running along its summit, and it appears to run out before reaching the lateral suture. The width between the posterior extremities of cheek-sutures is considerably greater than between the anterior extremities or between the ocular lobes. Glabella without furrows.

This beautiful species I have found only in breaking up some fragments of fine dark shale sent me from Coldbrook by my friend G. F. Matthew. It is associated with *Microdiscus Dawsoni*, and *Paradoxides lamellatus*.

Conocephalites Aurora, Hartt, MS. Resembles *C. Ouangondianum*, but differs in wider head, more depressed, anterior margin more broadly rounded, and border more strongly reflexed and elevated, etc. Rare at Ratcliffe's Mill.—N. B. Survey and C. F. Hartt.

Conocephalites Thersites, Hartt, MS. Differs from the last and also from *C. Ouangondianum* in the front margin being broad and flat, and bordered by a low narrow flattened fold or ridge, etc. Glabella in the cast has three pairs of very short raised lines on the sides. Very rare at Ratcliffe's Mill.—J. W. Hartt.

Conocephalites gemini-spinosus, Hartt, MS. Resembles *C. Mat-*

thewi, but with wider and less elevated marginal folds, cheek-lobes much more gibbous and semi-ovoid, etc. Sparsely sown with minute spines, grouped two and two. Rare at St John.—C. F. and J. W. Hartt.

Fig. 227.

Conocephalites Hallii (?).

Conocephalites Hallii, Hartt, MS. (Fig. 227). Well separated from all the others by its very convex, narrow, and long glabella, ovate, or cylindro-conical; as well as by its strongly rounded sub-angular outline in front, and by its peculiar anterior marginal fold. Not common at Ratcliffe's Mill.—N. B. Survey and J. W. Hartt.

Conocephalites quadratus, Hartt, MS. Head minute, transversely oblong, twice as long, slightly curved in front, straight behind, very flat; a narrow elevated fold, convex in front, concave behind, and somewhat inclined backward, goes round the margin. Very rare at Coldbrook.—Mr Matthew's cabinet.

Conocephalites neglectus, Hartt, MS. Glabella regularly semi-elliptical; length, exclusive of occipital ring, about two-thirds of width at base, moderately convex. Highest at middle of base and sloping with a regular curve toward the front. Traces of two pairs of glabella furrows on the sides. Occipital furrow deep and concave. Occipital ring with straight parallel margins, narrow with a short conical spine directed upward, etc. Very rare at Coldbrook.—Mr Matthew's cabinet.

Conocephalites formosus, Hartt, MS. Head trapezoidal in outline, the anterior and posterior margins approximately parallel, and the former of less extension than the latter. Glabella as wide at occipital furrow as long, narrowed in front, and broadly rounded, with straight sides,—three transverse furrows dividing it into almost equal parts, etc. Not very common, Ratcliffe's Mill.

Conocephalites, n. s. (?), Hartt, MS. Resembles *C. tener*, but has much shorter head and glabella, and very high anterior marginal fold. Very rare at Ratcliffe's Mill.

Microdiscus Dawsoni, Hartt, MS. (Fig. 228). Cephalic shield semi-lunar, with thickened border crossed by numerous grooves running perpendicularly to the circumference. Glabella convex, narrow, rounded in front, conical and pointed behind, projecting beyond posterior border, without furrows or occipital groove. Cheeks convex, no eyes, and no traces of sutures. Posterior angles of shield with backward projecting spines. Pygidium sub-triangular, with curved outlines, rounded in front and behind. Middle lobe distinctly marked, and divided

Fig. 228.

Microdiscus Dawsoni, head, mag.

into six segments. Lateral lobe also divided, furnished with a narrow border.

This pretty little species I have never detected in the shales from Ratcliffe's Millstream, but it occurs quite abundantly in the shales of Coldbrook. All the specimens I have seen were collected while breaking up some fragments of slate sent me from that locality by Mr Matthew. I am not aware that it is found in St John; I have never collected it at that locality. It always occurs broken, the cephalic shields and pygidia being separated.

Note.—Mr Hartt had originally described this species under the new generic name of *Dawsonia;* but Mr Billings regards it as a species of *Microdiscus* of Salter. The surface has a very fine granulation not shown in the figure, and the grooves of the border are also more distinct.

Agnostus Acadicus, sp. nov. (Fig. 229). Head minute, transversely-elliptical or sub-circular, breadth and length about equal, convex but very depressed, outlines in front and on the sides slightly straightened. A narrow flattened and but very slightly elevated border goes round the front and lateral margins. This is separated from rest of shield by a narrow, shallow, flat space, or groove, which, on going posteriorly along the lateral margins, loses gradually in width toward the posterior angles of shield, which are rounded. Glabella a little less than two-thirds the length of shield, long elliptical, depressed convex, but more elevated than other parts of the shield, about twice as long as broad, bounded anteriorly and laterally by a sharp rather deep groove concentric to the outer one above described. A well-marked transverse furrow arching backwards separates the anterior third of the glabella as a sub-circular lobe. Posterior part of glabella rounded, but impressed on each side by a little lobe situated in the angle between the cheek-lobe and the glabella. These little lobes are about one quarter the size of the anterior glabellar lobe. Cheeks of the same width throughout, and uniting in front of the glabella, being bounded by the two concentric grooves above mentioned. Posteriorly they are rounded; in width they are rather greater than the glabella. They are convex, more elevated along their inner margin, but sloping outward, roundly, and evenly. Glabella with its lobes project considerably beyond posterior margin. Surface smooth. Pygidium of this species (?) of about the same outline as cephalic shield. The posterior and lateral margins have a slight raised border, separated from lateral lobes by a shallow but well-marked groove running

Fig. 229.

Agnostus Acadicus, head and pygidium, mag.

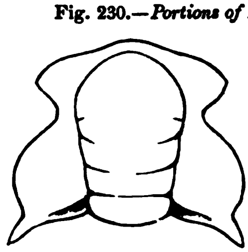
parallel to the margin. This groove widens at the point where it bends to go forward along the sides, in such a way as to encroach on and thin out the marginal fold, and, just before reaching the anterior margin, it narrows itself from the inner side so as to cause the lateral lobes to widen somewhat anteriorly. These are narrow, flattened, about half as wide as the middle lobe, narrowing to a point just behind the middle lobe where they do not unite. The medial lobe is about five-sixths of length of pygidium, shield-shaped, flattened, convex, more elevated than the lateral lobe. Its anterior border is slightly concave in the middle. The lateral angles are rounded, and the lobe is contracted a little anteriorly. It is bounded by two deep and well-marked furrows, which join one another in the middle of the marginal furrow, forming a pointed arch.* Medial lobe projecting farther forwards than the lateral ones. A little spine is situated on its mesial line about one-fourth its length from front. Surface smooth.

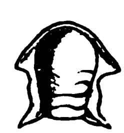
The pygidium and cephalic shield, from which the above descriptions were drawn up, were collected by my father and myself at St John, near the residence of W. R. Burtis, Esq., from shales of the lower part of the Acadian group. They were associated with *Conocephalites Baileyi* and *C. Matthewi*, *Orthis Billingsi*, etc. The two parts are separate, and each is represented by but a single specimen. I have little hesitancy in referring the one to the other. The glabella seems to be marked by a broad but faint transverse depression just behind the anterior glabella furrow. There are indistinct traces of an anterior articulating border to the pygidium. Both the specimens figured are casts.

Agnostus similis, Hartt, MS. Differs from the last species in its straight sides, wider marginal groove, and more distinct marginal fold. Cheek-folds narrower in front of glabella. The pygidium shows similar difference of proportion. Ratcliffe's Millstream, somewhat rare.

Paradoxides lamellatus, Hartt, MS. This is a small species distinguished from several others found with it by the presence of a number of sharp perpendicular laminæ on the anterior lobe of the glabella.

Fig. 230.—*Portions of Heads of Paradoxides.*



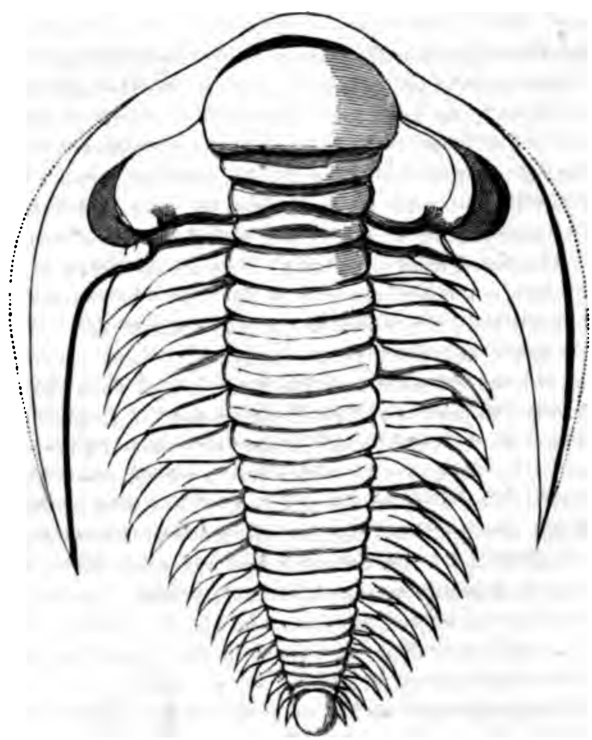


* More so than in the figure.

Mr Hartt recognises several other species of *Paradoxides*, but has not found time to work out their characters in detail; and this is rendered particularly difficult by the circumstance that the thin crusts of these creatures appear to have suffered even more from distortion than the other fossils imbedded with them.

The descriptions above given, with the fact that some of the layers are perfectly loaded with fragments of Trilobites, will serve to show the exceeding richness of this ancient fauna, and to indicate its relations to Primordial life in other parts of the world. These remarkable fossils deserve, however, much more full and detailed illustration than that which I have been able to give them; and many additional species will no doubt be found.

Fig. 231.—*Paradoxides*.



Restored by Mr Matthew from fragments found at St John, and probably belonging to a species indicated in Mr Hartt's MS. by the name *P. Micmac*.

CHAPTER XXV.

THE HURONIAN AND LAURENTIAN PERIODS.

INTRODUCTORY REMARKS—THE HURONIAN SYSTEM—THE LAURENTIAN SYSTEM—SUMMARY OF THE GEOLOGICAL HISTORY OF ACADIA—CONCLUSION.

THE formations last described carry us far back through the long ages of the earth's geological history to the beginning of the Palæozoic period; but still older rocks, indicating still earlier periods, are known to geologists. These, until lately, were regarded as azoic, or destitute of remains of life; but the discovery of *Eozoon Canadense* now entitles them to the name EOZOIC, or those that indicate the morning of that great creative day in which the lower forms of animal life were introduced upon our planet. Formations of this age occupy great breadths in the northern part of the North American continent. All that rocky and hilly region on the north side of the St Lawrence Gulf and River, constituting the Laurentide Hills, reaching from Labrador to Lake Superior, and the extension of it to the south in the Adirondac Mountains of New York, consists of Laurentian rocks, and these are skirted on the south, more particularly on the shores of Lake Huron, by the newer Huronian series, which, however, like the first, underlies all the Silurian formations, The rocks of both these great groups, as might have been anticipated from their vast antiquity, and the vicissitudes which the earth has undergone since their formation, are in a highly metamorphic state. Still there is good evidence that, like the altered Silurian rocks above described, they were originally sedimentary deposits, formed in the sea, and subsequently brought into their present state.

Until a few years ago, we had no evidence of the existence of these old formations in Acadia, or indeed elsewhere on the Atlantic coast south of the Gulf of St Lawrence, other than the vague suspicion that some of the metamorphic rocks of unknown age might possibly be referred to these periods. The discovery of the Primordial fossils

noticed in the last chapter has however, among other important results, enabled Professor Bailey and his able coadjutors to introduce into his "Observations on the Geology of New Brunswick" the two great groups of rocks which stand at the head of this chapter, while Mr Murray has recognised the Laurentian in Newfoundland, and a considerable area on the banks of the Lower Hudson has also been referred to the same period. These discoveries indicate a second long line of outcrop of Laurentian rocks parallel to that previously known, and separated from it by broad areas of Silurian, Devonian, and Carboniferous rocks. They also show that immediately after the Laurentian period, not only the breadth of the American continent in the north was marked out by these rocks, but also the direction of its eastern coast.

Huronian Series (*Coldbrook Group*).

Under the St John or Acadian series, in the vicinity of St John, and more especially at Coldbrook, there occurs a group of unevenly bedded rocks, evidently marking a period of much disturbance, and consisting, in large part, of conglomerate and of beds which seem to be of the character of volcanic tufa or indurated volcanic ash. In mineral character these beds closely resemble the Huronian of Georgian Bay, and as they underlie the Primordial slates of St John, I think we are fully justified in assigning them to this age. Should this view prove correct, the occurrence of these peculiar beds in New Brunswick, and also in the basin of the great Canadian lakes, will constitute an interesting illustration of the existence of similar physical conditions at the same time in widely separated areas, and will increase our appreciation of the geological importance of that period of physical disturbance which seems to have separated the quiet seas of the Laurentian with their reefs of *Eozoon* from the equally quiet conditions of the Lower Silurian ocean.

Though visible only along a line of outcrop about thirty miles in length, and a few miles wide, these Huronian beds attain in one locality, according to Mr Matthew, a vertical thickness of not less than 7000 feet. In other places, however, their thickness is stated to be only 150 feet. On this difference of thickness, and the composition of the group, Mr Matthew bases the following remarks:—

"These figures indicate that the ancient continent, previously elevated above the sea, sank under the accumulated weight of Huronian sediment to the extent of one mile and a half or more in that short distance, and that a coast-line near the position now occupied by the city of St John limited the Huronian sea to the eastward during a great part of this period.

"Its opening, if we may judge by the lowest member known, was marked by the accumulation of littoral sediment. To this succeeded an epoch when igneous eruptions commingled molten matter, scoria, and fragments of rock with the fine mud resulting from the wearing of the Azoic continent. After an interval of time, during which the arenaceous shales of No. 3 were formed, these conditions were again repeated in a still greater accumulation of volcanic ashes, tufa, etc., which, as the pre-existing land sank beneath the waters, spread as a thin deposit further west.

"The whole was eventually covered by the red and purple sediments of the Upper Division, which are more uniformly distributed, and are *conformably* surmounted by the lowermost strata of the Lower Silurian formation, thus becoming, like the Cambrian of Britain, the 'basement segments of the Silurian system.' And although Professor J. D. Dana classes these fundamental rocks of the Palæozoic series as Azoic, he remarks, that 'should the Huronian rocks be hereafter found to contain any fossils, they will form the first member of the Silurian.'

"In general characters there is a remarkably close resemblance between this formation and the Huronian of Canada, notwithstanding the wide extent of country which intervenes. Both are largely composed of erupted materials, diorites, tufas, and volcanic mud: hardness, and obscurity in the lamination of the slates is a feature in common; and here, as in Canada, slate conglomerates may be seen of a texture so compact and uniform that the inclosed masses are distinguishable only by a difference of colour."

The structure and composition of the series are thus given by Mr Matthew, in ascending order:—

"*Lower Division.*

"1. Coarse red conglomerate (with an abundance of quartz pebbles) and red sandy shale.

"2. Dark porphyritic slates and trap, with slate conglomerate, trap-ash, and tufa.

"3. Gray and ferruginous arenaceous shale and sandstone, becoming, when altered, a laminated compact felspar or felspathic quartzite.

"4. Pale-green (weathering gray) slate, stratification very obscure [apparently an indurated volcanic ash], with slate conglomerate, ash-beds, and tufa.

"*Upper Division.*

"5. Red and gray conglomerate and red shale. Red and purple grit and sandstone.

"Of these beds, Nos. 1, 2, and 3 do not extend so far west as St John, and No. 4 diminishes very much in bulk in the rear of the city, where it fills inequalities in the uppermost beds of the Portland (Laurentian) series."

Professor Bailey makes the following remarks on the age of these rocks:—

"The facts upon which depend the determination of this question have already been given in the remarks on the age of the Portland series, where also a parallelism is suggested between the Coldbrook rocks and those of the Huronian series of Canada. The parallelism is apparent, partly in the fact that the former, like the latter, underlie the rocks of the Potsdam group (of which the St John slates are here the representatives), and partly in their mineral characters and the absence of fossils.

"It is impossible to read the description given of the Huronian series in the reports of the Canadian Survey, without being struck by the close resemblance which exists between the members of that series, and what has been termed in New Brunswick the Lower Coldbrook group. In both the prevailing rock is a hard compact slate, almost universally of a dull grayish-green colour, with which are associated pink and white, or greenish-white felspathic quartzites, and at the base of the series, dark gray sandstones and conglomerates. In both, also, dioritic or greenstone dykes are common, as well as stratified amygdaloidal traps, the igneous outflows penetrating the rocks as well as lying in regular beds among the strata, in which they have produced excessive alteration. It will thus be seen that the two formations are alike in their general character, as well as in the conditions under which they were produced. Indeed, the resemblance is much stronger than would naturally be expected in series so widely separated.

"In passing to the upper member of the Coldbrook group, the task of establishing a parallelism with either of the Canadian series is much more difficult. Unless we regard the red quartzites and jasper conglomerates of the Huronian rocks (Nos. 7 and 8 of the section given in the Canadian Reports, near the Thessalon River), as the equivalents of the red conglomerates and sandstones of the New Brunswick group, no rocks approaching the latter in character are found, with the exception of the red sediments associated with the copper-bearing rocks of Lake Superior. As these, however, have been shown to be the probable equivalents of the Chazy group, which occupies a higher horizon than the Potsdam beds, which here overlie the rocks of Coldbrook, we must, for the present, be content to con-

sider their precise position as uncertain, only remembering that they constitute a series lower than the Primordial rocks, at the base of the Silurian."

The rocks of the lower part of the Coldbrook group being much harder than those of the upper member, and than those of the St John group, present a marked feature in the topography of the country, projecting in a bold and rugged ridge, well marked for some distance to the eastward of St John.

The Huronian of Western Canada is rich in metallic minerals, more especially in copper; but that of New Brunswick has not as yet afforded useful minerals. Indications of copper and lead, however, occur in rocks referred to this age on the Hammond River, near Quaco, and in other localities specular iron has been observed.

It is to be observed that while on Lakes Huron and Superior the lower Silurian rocks of about Chazy age rest unconformably on the Huronian; at St John, the Primordial shales of the Acadian group, which are, however, much older than the Chazy, appear to repose conformably on the Coldbrook series.

Laurentian Series (*Portland Group*).

Regarding the group of rocks last described as Huronian, there seems no alternative but to assign the great mass of calcareous and gneissose rocks underlying the Coldbrook group to the Laurentian. These rocks form an anticlinal northward of the Coldbrook group, and occupy an area about forty miles in length and from two to eight miles wide. In the immediate vicinity of St John, they are overlaid, apparently conformably, by the Coldbrook group. They may be observed elsewhere to be covered unconformably by rocks of Devonian and Carboniferous age.

When examining these rocks several years ago, I was struck with their resemblance to the Laurentian of Canada; but as nothing was then known with certainty as to the age of the St John rocks, I could not venture to assign them to so ancient a period. Their mineral character, as it then presented itself to me, is described as follows:*—

"The oldest rocks seen in the vicinity of St John are the so-called syenites and altered slates in the ridges between the city and the Kennebeckasis River. These rocks are in great part gneissose, and are no doubt altered sediments. They are usually of greenish colours; and in places they contain bands of dark slate and reddish felsite, as well as of gray quartzite. In their upper part they alternate with white and graphitic crystalline limestone, which overlies them in

* Journal of Geological Society, vol. xviii.

thick beds at M'Closkeney's and Drury's Coves on the Kennebeckasis, and again, on the St John side of an anticlinal formed by the syenitic or gneissose rocks, at the suburb of Portland. These limestones are also well seen in a railway-cutting five miles to the eastward of St John, and at Lily Lake. Near the Kennebeckasis they are unconformably overlain by the Lower Carboniferous conglomerate, which is coarse and of a red colour, and contains numerous fragments of the limestone.

"At Portland the crystalline limestone appears in a very thick bed, and constitutes the ridge known as Fort Howe Hill. Its colours are white and gray, with dark graphitic laminæ; and it contains occasional bands of olive-coloured shale. It dips at a very high angle to the south-east. Three beds of impure graphite appear in its upper portion. The highest is about a foot in thickness, and rests on a sort of underclay. The middle bed is thinner and less perfectly exposed. The lower bed, in which a shaft has been sunk, seems to be three or four feet in thickness. It is very earthy and pyritous. The great bed of limestone is seen to rest on flinty slate and syenitic gneiss, beneath which, however, there appears a minor bed of limestone."

Their structure is more fully represented in the following section by Mr Matthew. The order is ascending:—

"1. Gray limestones and dolomites (?) of great thickness, with beds of clay slate, occupying the middle of the peninsula which separates Kennebeckasis Bay from the Bay of Fundy.

"2. A mass of syenite and protogene, probably metamorphosed sediment.

"3. Gray and white limestones and beds of syenitic gneiss.

"4. Gray and reddish gneiss, conglomerate, and arenaceous shale, altered, resembling syenite and granulite. Arenaceous shale and gray quartzite. Dark flinty slate, with oval grains (black).

"5. Graphitic shale and pyritous slate, frequently alternating with gray and white limestones and dolomites (?). The beds thinner, and alternations more frequent, towards the top."

I have searched in vain, in the specimens in my possession, for indications of the characteristic fossil of the Laurentian; but there are traces of vegetable tissues, probably fucoidal, in the graphite and graphitic shale; and in rocks at Sand Point, referred by Mr Matthew to this group, there are worm-burrows and other markings, probably of organic origin. No representatives of the great deposits of iron ore found in the Laurentian of Canada and New York, have yet been recognised in New Brunswick. Nor do we know of anything corresponding to the interesting auriferous veins of Madoc, in Upper Canada (Ontario). The limestone of Portland, however, and other places,

has long been applied to economic uses; and, in some places, its texture is such that it would afford an excellent marble, the beauty of which is in some cases increased by the intermixture of green serpentine, exactly as in the Laurentian limestones of the Ottawa. Graphite also occurs in large quantity, as already mentioned, and though its quality is coarse and impure, it is possible that by subjecting it to the processes of mechanical purification now in use in other countries, a valuable product might be obtained from it. Its nearness to the city of St John, and to the great water power afforded by the river, constitute inducements for further attempts to render it useful.

Summary of the Geological History of Acadia.

Descending from the Modern period, we have now reached those rocks which constitute the lowest and oldest known foundations of our continents,—rocks which, in the Acadian provinces, have been almost wholly swept away or buried up in the formation of later sediments. That there were rocks older even than these, we know, from the circumstance that some of the beds above described are of a fragmental character. That some forms of animal and vegetable life already existed upon our earth—some of the creeping things of the waters—we also know; but of the old rocks which furnished the material of the Laurentian beds, or the land which may have been composed of them, we know nothing,—perhaps we never shall know anything,—at least from the records of the rocks. Here, then, we may turn from our descent into the bowels of the earth, and, retracing our steps, emerge once more into the light of day. In doing so we may lightly glance, in the historic or ascending order, at the several formations which we have described in detail in the opposite or descending method.

Beginning with Laurentian Acadia, we have before us an ocean of whose shores we know nothing; but in whose depths sandy and argillaceous sediments are being deposited, and animals and plants of the simplest structure are building up coral-like reefs, and accumulating masses of fetid muddy vegetable matter,—the whole to be, in process of time, converted by the magical alchemy of mother earth into crystalline gneiss, marble, and graphite. As ages roll on, and carry us into the Huronian period, the bed of this quiet sea is broken up, rocky ridges are exposed to the destructive action of the waves, volcanoes belch forth their lavas, and discharge their showers of ashes and scoriæ.

Another geologic age rolls by, and we see stretched out before us the northern nucleus of the American continent extending westward

from Labrador, a rocky, lifeless continent, in so far as we know. Along its shores are spread out muddy bottoms swarming with strange forms of crustaceans and shell-fish; and, in its more profound depths, are being slowly produced the great coral reefs which are to form the Lower Silurian limestones. In the area representing the Acadian provinces, shallow waters, invaded by muddy and sandy detritus, appear to have prevailed, with gradual subsidence of the bottom of the sea.

The Upper Silurian period would seem to have been introduced by new and extensive physical changes, which had the effect of producing greater inequalities of the sea-bottom, and ultimately a deeper sea, though perhaps more limited in area. At this time, also, extensive processes of elevation and disturbance were in progress along the Appalachian chain, and must have tended to separate more completely the Acadian area from that of the central part of North America. These movements were further connected with an entire change of the animal life of the region—a change, however, not sudden but gradual—and in the course of which, it would appear that many species which had long previously existed in other parts of North America, extended themselves over the Acadian area.

As the Upper Silurian period approached its close, and the sea-bottom had been loaded with many hundreds of feet of arenaceous, argillaceous, calcareous, and ferruginous sediment, another series of physical changes supervened. New lands were thrown up, and—still more wonderful change—these lands were clothed with a rich vegetation; and the oldest known land animals, delicate and beautiful insects — water-born but air-dwellers — flitted through its shades. With these changes came another and even more thorough revolution among the living things of the seas.

But while the Devonian rocks were being built up, the older sediments, buried under these newer beds, had been subjected to the intense action of the earth's pent-up igneous agencies; and, at the close of the period, it would seem as if the solid crust had given way, slowly and gradually, to the superincumbent weight, along certain lines; while in others the edges of the beds were tilted up, and the whole surface of Acadia was thrown into a series of abrupt folds,—great masses of plastic granitic matter invading every opening in the shattered masses. This period surpasses every other, in the geological history of the eastern slope of the American continent, in its evidences of fracture of the earth's crust. To this period we must refer the greater part of the intrusive granites of Eastern America, and to it also is referable the greater part of the metamor-

phism of the Silurian rocks, and the origin of the numerous metallic veins by which these are traversed.

This great earth-storm of the later Devonian left the surface of Acadia with its grand features marked out as they are at present; and the wide wooded swamps of the Carboniferous, and the sea areas in which its beds of shells and corals were depicted, occupied the present valleys of the country, and were limited by the same ridges of folded Silurian and Devonian rocks, which form the highest hills at present. So close is this correspondence, that the limits of the older formations on the map must very nearly mark the coast-lines of Carboniferous Acadia at the epoch of the Carboniferous limestone. For the present interests of Acadia, the great Devonian disturbances which charged the older formations with metallic minerals, and tilted up to the surface the great beds of iron ore, and the succeeding growth of the coal accumulations of the Carboniferous period, were the most important of all its geological changes, as being the sources of its great mineral wealth. Yet these momentous eras are not to be taken by themselves, but as links in a great chain of processes, with all the parts of which they are more or less closely connected.

Here we may pause for a moment to glance at the map, and to observe the three broad bands of Lower Silurian rock, portions of which appear on it, all of them running in a north-east and south-west direction. The most northern of these is seen only on a corner of the map, skirting the south side of the St Lawrence; but it is the most important of the whole, extending far to the south-west through Canada and the United States, constituting, with the exception of the Laurentian already mentioned, the oldest portion of the great Appalachian breast-bone of North America. The second is that extending across New Brunswick into Maine, and thence southward along the coast-line of the United States. The third is the coast series of Nova Scotia, extending to the north-east into Newfoundland, but disappearing to the south-west under the Atlantic. All these are auriferous and otherwise metalliferous, and they constitute three great lines of upheaval or ridging up of the earth's crust, in the troughs between which lie the Upper Silurian, Devonian, and Carboniferous areas of Acadia.

Of no geological period is the history better recorded in the Acadian provinces than the Carboniferous, in regard to which they may even be considered as a typical region, presenting the formations of that period in the greatest possible thickness and variety, and exhibiting in a very perfect manner, and with features not as yet paralleled in

other regions, the terrestrial life of that very interesting era. The wonderful history of the Carboniferous period has, however, been so fully detailed above, and is in itself so ample, that I shrink from any attempt to sum it up here.

We now reach a blank in the geological history of Acadia—a blank represented only by certain elevations and disturbances of the Carboniferous beds, which occurred during the period occupied in some other regions in the deposition of the Permian rocks. This was succeeded by the local but important volcanic outbursts which accompanied the probably rapid deposition of the Triassic red sandstone, an association of volcanic phenomena with the hasty deposit of coarse sediment stained with oxide of iron, which had occurred before in the Lower Carboniferous, in the Lower Devonian, and in the far earlier Huronian.

The Trias of Prince Edward Island alone gives us, in the bones of *Bathygnathus*, a single glimpse of the reptilian life of the Mesozoic "age of reptiles," so richly exhibited in some other countries.

A blank in this monumental history of enormous length succeeds the Triassic period, and Acadia with the neighbouring parts of North America was probably, during these long Mesozoic and Tertiary ages, a part of an extensive continental area, in which animals and plants, characteristic of those periods, no doubt flourished, but have, so far as we know, left no traces of their existence.

The next vicissitude of which we have any record is that mysterious glacial period, which I am inclined to regard as one of subsidence under an ice-laden sea, in so far at least as Acadia is concerned. Certain it is that no deposit similar to the boulder clay had occurred previously in Acadia, unless indeed we may regard some of the coarser conglomerates of the Carboniferous period, as evidence that ice was grounding on the coasts on which the vegetation of the coal formation was flourishing. Probably at this period Nova Scotia and New Brunswick were in circumstances very nearly the same with that of the great Newfoundland banks at present. Under any view, nothing is more remarkable in the geological history of the earth than the almost universal subsidence and glaciation which seem to have affected the Northern Hemisphere at this period, geologically so recent. Little by little, terrace after terrace, the land rose from the glacial submergence; and, as it rose, it began to be peopled with a gigantic race of quadrupeds which gradually gave place to those now existing; the extinction of the Mammoth and Mastodon having probably had relation to the gradual increase of the surface of the land, and its warmer and drier summers. Had these creatures

finally disappeared before the advent of the Micmac and Maliseet? We know not; but in so far as negative evidence is entitled to weight, we may suppose that they had; and that the human occupation of Acadia may not be of older date than the origin of the historic nations of the old world. The Red man still survives, with the remnant of the wild animals which fed his forefathers, and of the forests which sheltered them; but now the towns and cities of civilized man grow up on the borders of our rivers and bays, his fields spread over the land, his sails dot the surface of the waters, his mines penetrate the deeply hidden stores of subterranean wealth, while his ever active mind studies with penetrating insight the monuments of that strange series of creative processes by which in the counsels of Almighty wisdom its present destiny was worked out. What next? Geology cannot answer the question; and the geologist, as he lays down his hammer and his pen, can only utter the prayer that in the future history of this old world, in whatever of new development and higher glory its Maker may have in store for it, Acadia and its sons and daughters may bear a worthy and a happy part.

Conclusion.

In the preceding pages, I have neither sought nor avoided the discussion of those questions on which geologists are at present divided in opinion, in so far as these questions are raised by the history of the formations developed in the Acadian Provinces. I have, however, made such discussions subordinate to the statement of the facts immediately under consideration; and, for this reason, they will be found scattered in various places throughout the work. I may now shortly sum up my conclusions with reference to a few of the more important of these disputed points.

The hard-fought field of glacial denudation, striation, and boulder drift, I have traversed in the Chapter on the Post-pliocene, and have endeavoured to show that the phenomena of the boulder clay and drift in Eastern America are to be accounted for not by a universal glacier; but by local glaciers, drift ice, and the agency of cold northern currents, in transporting materials and eroding the surface of a partially submerged continent.

On the modern notion of "homotaxis," as distinguished from actual contemporaneity of formations on the same geological horizons, I have fully stated my views in introducing the history of the Carboniferous period, and have shown reason for believing that the formations of this great period in America are exactly, and even in their subdivisions, synchronous with those known by the same names in Europe.

I would also invite the attention of geologists to the doctrine of equivalent geological cycles, as stated in that chapter; believing that, in spite of all local diversities, such general cycles of geological change will at length be fully established. For the present, I am aware that there is a tendency among some of the younger geologists to extend to the whole world, and to all time, the exceptional coast-conditions of small areas, and very limited faunas; but this attempt to raise the exceptions to the rank of the rule cannot deceive those whose studies have made them familiar with the enormous areas of deposition and life-distribution in the modern ocean, and with the still more uniform conditions of the Palæozoic land and sea.

With respect to theories of metamorphism and the production of what have been termed "Indigenous" crystalline rocks, the phenomena observable in Acadia point out that the heat of the great igneous masses of the interior of the earth's crust has been mainly instrumental in effecting such changes, though much must be allowed for the original chemical differences of the beds. There is also very striking evidence of the power of huge Plutonic masses to melt their way, if we may so speak, through the aqueous beds, with very little mechanical disturbance, and only a limited amount of metamorphism in the immediate vicinity of such masses. Nor can there be any question that the igneous masses themselves have been much modified in their chemical constitution by beds through which they have passed, so that there is a certain correspondence between the character of igneous rocks and that of the beds which they penetrate. In addition to all this, we have bedded traps and tufaceous beds composed of the debris of igneous rocks, readily assuming under metamorphism the aspect of Plutonic dykes. It is clear that a want of careful analysis of facts so complicated may readily lead to the confused and contradictory doctrines on the relations of the metamorphic sediments and the "exotic" Plutonic rocks now too prevalent.

I have not been able to find, in the remarkably complete series of fossils afforded by the Carboniferous of Nova Scotia, any evidence of the gradual transmutation of species by natural selection or any other cause. On the contrary, species appear without any manifest cause, and remain unchanged, or with very limited varietal modifications during very long periods. I admit, however, that in the case of certain species of wide range and long continuance, as *Productus cora* and *Alethopteris lonchitica*, for example, varietal forms can be observed to be characteristic of certain places and beds; and that if we were to regard the varieties as species, and the latter as sub-genera, then such supposed species might be regarded as transmutable into each other,

inasmuch as they pass into each other by indefinite gradations; but I cannot regard such varietal forms as true species.

The relations of the Carboniferous to the Devonian flora appear to militate in a positive manner against the theory of transmutation. The Devonian flora of Eastern America, of which there are now known nearly one hundred species, affords all the principal generic forms of the Carboniferous. A few of its species are identical, but the greater part are distinct; and this distinctness is even more marked in the Lower Carboniferous than in the Coal formation. While, therefore, a few species continued unchanged through all the vast time of the Devonian and Carboniferous, others disappeared at the close of the Devonian and were replaced by distinct species in the Carboniferous, and all this without any material improvement or elevation of type.

It may be added, that in New York and Ohio, where no physical break separates the Devonian and Carboniferous, the change of flora takes place in the same manner, and that the floras of the Devonian and Carboniferous are now too well known, and that over too large an area to allow us to explain this by "imperfection of the record."

Again, if we turn to the Primordial fauna of St John, we find there, as in similar horizons in Europe, several distinct types of animal existence already well defined, and none of them pointing by any character to the primitive *Eozoon* of the Laurentian rocks, which stands out as distinctly by itself as the two little land-shells of the Coal measures.

On the great question at issue between the "Uniformitarians" and "Catastrophists," I desire to occupy that middle ground to which I am glad to see that Lyell and Murchison, the two great leaders of geological opinion in Great Britain, tend in their later works. While the doctrine of the absolute uniformity of natural laws cannot be too strongly held, we must admit that periods of more and less energetic action of the great causes of geological change have alternated with each other over regions so extensive as practically to affect the whole world, and that the period of human observation has been probably too limited to enable us fully to appreciate the extremes of these oscillations. In other words, the long-continued operation of uniform causes, whether geological or astronomical, may lead to an accumulation of effects in certain directions, terminating in a change, cataclysmal in its character, and initiating a new train of causes perhaps under very different conditions. It is true that such a cataclysm may, in a broader view, be regarded as a part of the uniform order, just as a thunderstorm or an earthquake may be regarded as an effect of regular natural laws, as much as a tide or a current. Still we should beware

imiting the intensity or extent of such phenomena by our own t experience. Nor must we fail to consider that all successions implied progress, that every oscillation of the piston-rod, every of the wheels, urges the machine forward. Nothing can be more ent than the continued progress and development of both unorzed and organized nature on the surface of our planet, from the est periods of geological time to the present day. But our rience of existing causes has been too short to enable us fully to ze this, or to harmonize it with our notions of uniformity or catams or creative intervention. We are but infants in knowledge, we have been passengers in the ship of nature for so short a time the oscillations of the piston-rod may appear to us cataclysms oncilable with the steady motion of the wheels, and that we may be unable clearly to discriminate between the action of the lifeless hinery and that of the unseen hand and mind which regulate and le; and while we may readily discover motion and progress, the of departure and that of destination are alike invisible in the ance. Patient observation and thought may enable us in time er to comprehend these mysteries; and I think we may be much d in this by cultivating an acquaintance with the Maker and er of the machine as well as with His work.

APPENDIX.

(A.)—Micmac Language and Superstitions.

I referred in Chapter IV. to the fact that, in the judgment of my friend Mr Rand, there are strong points of resemblance between the Micmac and Maliseet languages and some of the older languages of Europe, and that these may still be traced in many root words. He has furnished me with a number of these which have occurred to him in translating the New Testament; stating that he merely presents them as genuine resemblances occurring in primitive aboriginal words, and the precise value of which he leaves to be estimated by philologists. They are undoubtedly too numerous and important to be purely accidental; though they may be accounted for either by supposing that the Algonquin languages, of which the Micmac is merely a branch, actually retain traces of roots derived from the Eastern Continent, or by supposing that in the formation of the language similar ideas as to onomatopœia occurred to the mind of the American Indian and his contemporaries in the Old World. In either case, the similarity indicates the claim of the American to kinship with the European; and the following list of words will illustrate a fact of some interest, whatever its value in philology. I have given merely a few of the examples communicated to me by Mr Rand, and have left out a great number in which the resemblances are obscured by change of consonants, such as the substitution of other sounds for "*r*," which does not occur in Micmac. The vowel *a* is sounded as in "father," except when marked short (ă), when it sounds as in "man." The other vowels are long, except where marked as short.

Pŭlĕs, a pigeon. Cf. *πελεια*.
Agĕ or *ahge*, earth. Cf. Heb. *aretz*, *γη*.
Padoos, a boy. Cf. *παιδος*.
Pegoon, a feather. Cf. *πωγων*.
Oo-lakŭn, a dish. Cf. *λεχος*.
Oktan, the main sea. Cf. *ὀκεανος*.
Alasoomk, I beseech. Cf. *λισσομαι*.
Agwŏltk, it is in the water. Cf. *aqua*.
Ep-āgwŏlt, it lies in the water; the Micmac name of Prince Edward Island.
Astow, in the sunshine. Cf. *æstus*.
Jŭn, a child. Cf. *juvenis*, *jung*, *young*.
Ancane, ancient.
Kĕkoo-nŭm, I have it. Cf. *ἐχω*.

Tŭbagŭn, a vehicle. Cf. *wagon*.
Taboo, two. *Seest*, three.
Wĕgălŭtk, to bark. Cf. ὑλακτεω.
Queetŭm, I seek. Cf. *quaero*, *quaestus*.
Mat-tuk, to beat. *Măttole*, I beat thee. *Mătŭnāgā*, I fight.
Cōmé, a harbour. Cf. κωμη.
Epsit, warmed. *Epsŭm*, I heat it. Cf. ἑψω.
Cubĭlakum, a cradle-board. Cf. *cubile*.
Nekokul, a spear. Cf. ἀκωκη.
Ankedasi, I think earnestly. Cf. *ango*, ἀγχω.
Ekai, I come. Cf. ἡκω.
Cheenum, a man. Cf. γενος.
Oo-dun, a town. Cf. *dun* and *dune*.
Ait, he says. Cf. *ait*.
Mitle, many. *Meg*, great. *Mal*, bad. Cf. *mickle*, μεγας, *malus*.
Well-ake, he is well. This root *well* occurs in many compounds.
'M-digin, a thumb. Cf. *digitus*.
'M-pak, the back. The prefix *'m* appears to be a remnant of an indefinite article.
Oolk, a ship. Cf. *hulk*, ὁλκας.
Keloos, good. Cf. καλος.
Keloos-oodee, goodness. Oodee in Micmac has the force with the English postfix hood, in childhood, etc.
Oonŭks, a wing. Cf. ὀνυξ.
Wigwam (*oikom*), house. Cf. οικος (Fοικος), *vicus*.
Weeka, his home. Cf. οικια.
Tem-sum, I cut it. Cf. τεμνω.
Mŭlŭk-ŏch, milk. A word which is one of the most primitive, and contained in most languages.
Moo, no. Cf. μη.
Kwis, a son. Cf. υἱος.
Nephk, he is dead. Cf. νεκρος.
Kwa, hail. Cf. χαιρε.
Kakayak, it fails. Cf. κακεω.
Tokoo, then. τοτε.
Kewkw, an earthquake. Cf. *quake*, *quatio*.
Aleā, to go. Cf. *ire*, *aller*, etc.
Ejikuladoo, I cast away. Cf. *ejicio*.
Wij, prefix signifying with.
Tan, when. Cf. ὁταν.

To these examples I may add an illustration from Mr Rand's Micmac version of St John, xix. 24, where the leading words in one of the clauses are very similar in Greek and Micmac.

Μη σχισωμεν, λαχωμεν.
Moo skwiska lakade-nĕch.
We shall not rend, but cast lots for it.

The superstitions, traditions, and astronomical notions of the primitive Micmacs also present points of similarity with those of other nations, and

Mr Rand's knowledge of their language has enabled him to collect many of these.

They believe in fairies, whom they call "Wiggŭl-laddŭm moochkĭk," very little people. They are supposed to be superhuman, immortal, living in caves and underground, and, like the fairies of other lands, coming out to dance, and disappearing in the day-time.

They also have a tradition of a primitive race of giants, "kookwĕs" (cf. γιγας), of great size, and cannibals.

By the term "Chinook," which is the actual name of a tribe of Western "flat-head" Indians, in historic times far removed from the Micmacs, they denote a northern people with hearts of ice, and so terrible that their very war-whoop was fatal.

They know of fauns or demi-gods, "*Migumoowesoo*," which haunt the woods, and sing and play exquisitely, seeking to entice unwary travellers. They have also seen mermaids of the true mythological type.

The ancient Micmacs had names for the principal constellations, but their degenerate descendants have lost most of these. They still know "Mooin," the Bear, or Ursa Major; and it is characteristic, that as Micmacs know that bears have not long tails, the stars of the tail of the Bear are called the "Hunters." Each of these has his name. The nearest is *Pŭlĕs*, Pigeon; the next is *Chigugéck*, Chickadee or Titmouse; the third is *Chipchiwitch*, Robin. These words are curious illustrations of the prevalent onomatopœia in the names of animals. A small star near one of the Hunters is his "Kettle," and Berenice's Hair is the "Bear's Den." The Evening Star they call *Neganoos*, the leader of the host. The Morning Star is *Ootă dă bŭn*, the herald of morning. The Belt of Orion they call the "Fishermen," and his sword the "Kings." Four stars in the form of a cross in the thigh of Antinous are called the "Loon." The Pleiades are named *Ajalkŭch*, the meaning of which is not known.

Lastly, they have a great traditional immortal patriarch, benevolent and powerful, "*Glooscap*," of whom they have many legends, and who has left his children, the Micmacs, because of their sins, but who will one day return when they are sufficiently humbled and penitent.

(B.)—Peat as Fuel.

It is not to be expected that, in the vicinity of the coal-fields, peat can be profitably manufactured for fuel; but in those parts of Nova Scotia and New Brunswick remote from the coal districts, there exist important deposits of this substance which may become economically useful. The principal disadvantage of peat as compared with coal is the large quantity of water which it contains, amounting to about 90 per cent. of the whole in the crude material, and even in the dried peat to from 20 to 35 per cent. This difficulty is partially obviated by thorough drying in the air, and more completely by pulverizing and compressing the peat, or by charring it, as is done in France. The only locality in Canada where peat is at present extensively worked is on the property of Mr Hodges, in Bulstrode, P. Q. The process employed is that of excavating the peat, reducing it to pulp, cutting it into square portions like bricks, and thoroughly drying it. The machinery employed

is placed in a barge, which excavates a canal, in which it floats as the work proceeds. Pressure is not employed. Peat prepared in this way is sold at 4 dols. per ton in Montreal, and has been used advantageously for the production of steam and in domestic fires. In Ireland and in Scotland attempts have been made on a large scale to use peat as a source of tar, coal-oil, and other products. In some cases the results have been profitable, in others the reverse. This appears to have depended partly on the processes employed, and partly on the quality of the material. Persons desirous of making further inquiry on this subject will find additional details in Sir W. E. Logan's Report on the Geology of Canada, 1863, and in a paper by Dr Hunt in the Canadian Naturalist for December 1864.

(C.)—Cone-in-Cone Concretions.

Every field-geologist is familiar with various forms of concretions, as of clay-ironstone, flint or chert and carbonate of lime, which occur in clays and similar beds, or in limestones. They are in general attributed to the mutual attraction of particles diffused through masses of sediment, and

Cone-in-Cone.

aggregating themselves around solid bodies as nuclei, or flowing into cavities of fossils and other places of least resistance. Such nodular arrangements are especially abundant in the underclays and other clay beds of the Coal measures, where the carbonate of iron formed by the action of decaying vegetable substances on the oxide of iron present in the sediment, has shown a singular aptitude for assuming such structures, and the nodules and nodular sheets of ironstone often contain fossils of much interest. In these nodular layers also, as well as in certain layers of hard argillaceous matter, we often find the remarkable structure to which this note relates. It consists of series of conical forms often running together into rows and ridges, and consisting of a series of concentric coats, whence the name "Cone-in-cone," given by the miners. The surfaces of the coats are also curiously marked with transverse ridges, giving a wrinkled appearance, so much resembling some organic structures as to deceive some persons into

the belief that these curious forms may be fossils. The figure represents somewhat perfect example, selected from a series of specimens kindly ser to me by H. Poole, Esq., from the beds overlying one of the Coal-seam at Glace Bay, Cape Breton. Previously to the receipt of these specimen I had thought little as to the origin of these forms, but a careful study c Mr Poole's specimens led me at the time, in exhibiting them to the Natura History Society of Montreal, to state my belief that they are produced b "concretionary action proceeding from the surface of a bed or layer, an modified by the gradual compression of the material." Subsequently, a the Meeting of the American Association at Burlington, Professor Marsl of Yale College, in the course of an able dissertation on the origin of th so-called "*Lignilites* or *Epsomites*," incidentally referred to the "Cone-in cone," and attributed it to the same cause, though unaware at the tim that this explanation had occurred to any other person.

Taking this view of the origin, these concretions serve as an interestin illustration of the curious imitative forms sometimes assumed by concretion and also of the twofold movement of particles of matter in sediments under going consolidation under the double influence of mutual attraction an of mechanical compression. Farther examples of the effects of these force may be found in the formation of ordinary nodules, the infiltration of th cavities of fossils, the slickensiding of underclays and other beds full o vegetable matter, by the giving way of the latter under pressure, and th curious crushing of erect jointed stems of Calamites into rows of disc-lik bodies, representing the firm nodes, while the intermediate portions hav collapsed (see figs. at pp. 150 and 406). The remarkable distortion of fossil by pressure already referred to (p. 499), the nodular changes, and curiou minute crumplings which have taken place in the production of slaty struc tures, are also illustrations of that mobility of particles in consolidatin rocks, which must be invoked to explain the Cone-in-cone.

Cone-in-cone is found in the Coal-formation rocks of other countries tha Nova Scotia, being not infrequent in the clay ironstones of England. I is noticed by Professor Rogers and Professor Hall as occurring in th Devonian of Pennsylvania and New York, and I have observed it in one c the layers of fine laminated shale in the primordial strata of St John, Ne Brunswick.

(D.) Tabular View of the Lower Coal Measures.*

	Horton.	*Mill-Brook, Windsor.*	*Hillsborough, N. Brunswick.*	*Plaister Cove, C. Breton.*
Upper Coal-measures.	Not seen.	Not seen.	Upper sandstones and shales of South Joggins.	Not seen.
Middle Coal-measures.	Not seen.	Not seen.	Coal measures of Joggins, and Millstone-grit, or Lower Coal measures of Dorchester, etc.	Coal measures of Caribou Cove, River Inhabitants, and Ship Harbour. Sandstones of Strait of Canseau.
Lower Carboniferous Marine Limestones.	Limestone, marl, red sandstone, and gypsum of Half-way River and Windsor.	Same as last column.	Limestones, gypsum, and conglomerate of Dorchester and Petitcodiac R.	Limestone, gypsum, and marls of Plaister Cove.
Lower Coal-measures.	Dark clay shale and calcareous shale, with laminated limestone, dark micaceous flags, gray and white sandstone, and in the lower part some red sandstone. Plants, fishes, entomostraca, worm tracks, ripple and rain-marks, sun cracks, reptilian footprints, erect trees. Lower Horton, Wolfville, Horton Bluff, Half-way River (Paper by Sir C. Lyell, Geol. Proc. iv. p. 184. Paper by the author, Geol. Journ., vol. iv. p. 59. Obs. by the author in 1857.)	Thick white sandstone (debris of white granite), in places with quartz pebbles, fragments of plants. Dark micaceous flags and shales, obscure footprints, carbonaceous impressions, an underclay, a thin ironstone, gray coarse sandstone and conglomerate, white sandstone, carbonaceous shale, and black underclay. Near the bottom irregular and shore-like layers of coarse sandstone, shale, Lepidodendra. (Paper by Sir C. Lyell, *l. c.* Obs. by the author, 1857.)	Fine calcareous and highly bituminous shales, with thin beds of sandstone. Abundance of remains of fishes, seen at Petitcodiac River, above Dorchester, Albert Mine, and other localities westward of that place. (Paper by the author, Geol. Journ., vol. ix. p. 107.)	Hard sandstones and shales of gray and black colours, with obscure fragments of plants, resting on coarse gray conglomerate of great thickness. (Paper by author, Geol. Journ., vol. v. p. 335.)
Underlying Rocks.	Upper Silurian slates—unconformable.	Hard thick-bedded rock, resembling an indurated volcanic ash—no fossils; age uncertain.	Metamorphic rocks of Devonian age, in coast range of New Brunswick.	Slates, etc., of Cape Porcupine, etc., probably Upper Silurian.

* From paper by the author, Journal of Geological Society, 1858.

(E.)—Grand Manan.

This isolated portion of New Brunswick has hitherto been a blank in the geological map, and for this reason I insert here a note kindly communicated to me by Professor A. E. Verrill of New Haven, who, though he visited the island for zoological rather than geological objects, has given some attention to its structure.

"The stratified rocks of the island appear to represent at least two formations which are unconformable.

"The one, which is apparently the oldest, occupies the belt of low land and the shore cliffs from Whale Cove and Northern Head, along the whole eastern side of the island, to Grand Harbour, about the middle of the island, beyond which I have also seen outcrops of it in several places, but have not examined the whole extent. The same rocks compose Long Island, Duck Islands, Rosse's Island, Whitehead Island (in part at least), and nearly all the other small islands off the east side of Grand Manan. Inner Wood Island is, however, partly composed of conglomerate and fine-grained dark-red sandstone, with an easterly dip, which may belong to a higher formation; and Gannet Rock, upon which there is a lighthouse, was described to me as composed of conglomerates. The Three Islands, which are the most eastern, are in the main composed of rocks similar to the eastern shore of the main island, but upon the outer one I found also a bed of white crystalline limestone.

"The series of rocks alluded to are highly altered, much distorted and broken, and cut through by numerous immense dykes and masses of trap, and consist of talcose and clay slates, mostly grayish, but sometimes black, calcareous grits, altered gray sandstones, in one case with vegetable traces, but sometimes so indurated as to become quartzites, or, when impure, approaching a syenitic character. Included in these gray sandstones and slates near Pettee's Cove, there is a bed of black carbonaceous shale, very fissile, as if it ought to yield plant-remains, but I could find none. Included in similar rocks near the same place are several true veins of heavy-spar, mostly massive and pure, but in one case carrying some galena, copper, pyrites, etc. On Rosse's Island, inclosed in black slates, probably of the same age, there are enormous masses of white quartz, conspicuous above the general surface, some of them 100 feet or more across, and from 10 to 40 high. The dip of these rocks is so variable and irregular that no *general* statement can be made. Where least altered, it was often to the N.N.E. 45°, but at other times they were nearly vertical or even inclined to the S.W., varying in short distances.

"The second series of rocks occupy the northern end of the island to the west of Whale Cove. Commencing at this Cove and going west, we find first regularly columnar trap for a short distance, and then, apparently resting upon it, thick-bedded, regularly stratified massive rocks of various composition, but mostly amygdaloidal, trap-ash, and compact quartzoze rocks in beds 10 feet or more thick. These occupy the shore for about two miles, forming cliffs from 100 to 200 feet high. They are at times nearly horizontal, in other places dipping to the W. or S.W. about 10° to 20°. The amygdaloidal cavities contain calcites, stilbites, apophyllites,

etc., but seldom affording good specimens. Beyond these rocks, at the N.W. extremity of the island, the cliffs are very high, consisting of trap, often columnar, which continues for several miles; but I have been told that a stratified sandstone again appears for a short distance on the western side, north of Duck Harbour, where I have not been; but, from Duck Harbour to the southern end of the island, I found the cliffs to consist of trap, from 200 to 400 feet high (by estimate).

"Concerning the age of these massive stratified rocks, I can only offer the conjecture that they are Devonian from their *appearance* alone.

"Whether the red-sandstone of Inner Wood Island and conglomerate of Gannet Rock are of the same age is very uncertain."

On careful consideration of the above observations of Mr Verrill, in connexion with the structure of the neighbouring coast, I think it probable that the outer and older series above mentioned is either the equivalent of the Acadian or St John series or of the Kingston series, and that the traps with the associated sandstones may be Devonian or Upper Silurian. The colouring on the map represents one of these conjectures.

(F.)—New Minerals from Nova Scotia.

"Professor How announced in Silliman's Journal, Sept. 1857, the discovery, in the great bed of gypsum quarried at Windsor, of the rare boracic-acid mineral, *Natro-boro-calcite*, hitherto found only at Iquique in Peru. Its formula, according to Professor How, is—

$$\text{Na O 2 BO}_3 + \text{2 Ca O, 3 BO}_3 + \text{15 HO.}$$

With respect to the geological conditions of its occurrence, Professor How quotes from Professor Anderson of Glasgow the statement that, in Peru, the mineral is found in a district supposed to be volcanic, and embedded in the nitrate of soda deposits. He then remarks that, with a very few exceptions, boracic acid is found "either in directly volcanic regions, most abundantly as such, or as borax; and a well-marked case of actual sublimation of the acid from a volcano in the island of Vulcano, near Sicily, has been studied by Warrington; or in smaller amount, in minerals the products of recent or extinct volcanoes, as Humboldtite from ejected blocks of Vesuvius, and zeolites and datholite from trap of Salisbury Crags, New Jersey, and other places; or in minerals of purely plutonic or metamorphic rocks, as tourmaline, the rhodozite of Roze, and axinite—the species which contain it at all being few in number. It may be noticed also, that traces of this acid have lately been met with in the Kochbrunnen of Wiesbaden and in the waters of Aachen."

"If we may reason from the character of the majority of its situations, we may almost consider the volcanic or at least igneous origin of boracic acid so well established as to lead us, by its occurrence in the gypsiferous strata, to seek for some volcanic agency as the cause of their production. Such an origin has, I find, already been assigned to the gypsum of Nova Scotia by Dr Dawson. This formation has been shown to be a member of the Lower Carboniferous series, and is assumed to have arisen from the action of rivers of sulphuric acid more or less dilute, such as are known

to exist in various parts of the world, issuing from then active volcanoes and flowing over the calcareous reefs and bed of the sea."

The same able chemist, in 1861 (Silliman's Journal and Edin. New Phil. Journal), described a second boracic acid mineral, which he has named *Cryptomorphite*. It is, like the former, a borate of lime and soda, and its probable formula is stated to be :—

$$Na\,O,\ 3\,Ca\,O,\ 9\,BO_3 + 12\,HO.$$

Still more recently Professor How has kindly communicated to me a notice, shortly to be published, of a third mineral, found under similar conditions at Brookville and Newport, near Windsor, and which he proposes to name *Silico-boro-calcite*. It contains a large proportion of silica, and its formula is given as—

$$2\,Ca\,O\,Si\,O_2 + 2\,(Ca\,O\,2\,BO_3,\ HO) + BO_3,\ 3\,HO.$$

These minerals occur in small nodular masses in the gypsum and anhydrite, and are associated with glauber salt, and they have now been found by Professor How in several localities, and in some of those in considerable abundance. The natro-boro-calcite is said to occur in the ordinary gypsum only, while the silico-boro-calcite is found in anhydrite as well.

Professor How has also detected both the carbonate and sulphate of magnesia in the gypsum and associated rocks, though apparently not in large quantity.

Professor How has also recognised the mineral Pickeringite or magnesia-alum occurring as an efflorescence on the surface of slate at Newport. It is curious that this mineral, like natro-boro-calcite, had previously been found only at Iquique in Peru. It is also curious that it was found to be associated with small quantities of nickel and cobalt. The former metal had not previously been found in Nova Scotia, though not infrequent in the Lower Silurian, Huronian, and Laurentian, of Canada.

Professor O. C. Marsh, of Yale College, has communicated to Silliman's Journal (Nov. 1867) a notice of the mineral *Ledererite*, found by Jackson and Alger at Cape Blomidon. Professor Marsh regards this mineral as identical with *Gmelinite*, and attributes its peculiarities to the accidental presence of phosphoric acid and of minute crystals of quartz embedded in the specimens.

(G.) Mining Laws and Regulations.

In Nova Scotia the mines and minerals are under the general supervision of the Commissioner of Mines, from whom all necessary information and guidance can be obtained; and the laws relating to mines and minerals are of such a character as to afford all the encouragement that can be desired to legitimate enterprise.

In the case of *Gold*, "prospecting licences" are issued for periods of three months, and for areas not to exceed 100 acres. The fee is 50 cents per acre up to 10 acres, and beyond this 25 cents. Such licences may be renewed at half the above rates. On discoveries being made, the discoverer

is entitled to a lease for 21 years, under a royalty of three per cent. on the gross amount of gold obtained. Licences are also given for crushing mills. All the details as to rights of proprietors of land, and conditions of licences and leases, are carefully provided for by the law.

In the case of *Coal and Other Minerals*, licences to explore on tracts of five square miles in extent are granted for 20 dollars. These, however, are for twelve months, and may be renewed on application thirty days before they expire, and on payment of 20 dollars. The holder of an exploratory licence may select an area of one square mile, and secure the right of mining thereon on application and payment of 50 dollars to the Commissioner of Mines. Licences to work are for a term of two years, within which term the holder must commence effective mining operations, and continue the same in good faith. On expiry of the licence, the holder may obtain a lease, in the case of coal, until 25th August 1886; in the case of other minerals, for 21 years, subject to a royalty of five per cent. in the case of all minerals, except gold, coal, and iron. The royalty on coal is ten cents per ton of 2240 lbs. and on iron eight cents per ton. Larger areas than one mile may be granted by the Governor in Council in special cases. A variety of provisions as to details will be found in the law.

(H.)—Additional Information relating to Mines in Nova Scotia.

Coal.—According to the Report of the Chief Commissioner of Mines for 1867, the total yield of coal in Nova Scotia has fallen off from 601,302 tons in 1866, to 482,078 tons in 1867. This diminution is attributed solely to the derangement of trade relations with the United States, consequent on the abrogation of the reciprocity treaty. Unless these relations shall be re-established, other markets must be found, or manufactures must be established capable of consuming the coal within the colony. It is much to be desired that the attention of British capitalists should be directed to the openings for profitable investment in mining and manufacturing industry in Nova Scotia. Under any probable contingency as to the future political relations of the colony, such investments would be safe, and would probably increase in value.

1. *The "Drummond Mine" of the Inter-colonial Company, East River of Pictou.*—The explorations recently made by Mr Barnes, for the tracing of the outcrop of the main seam, have proved the undisturbed extension of the outcrop for more than half a mile to the south-west of the original opening, with every prospect of its still further continuation. According to Mr Barnes, there is now immediately available on this property an area of 480 acres of this great seam, having a vertical thickness of sixteen feet of the best quality of coal, and of course a similar or larger area of the underlying seams. The Company are now vigorously pushing forward the construction of a railway and the opening of the mine by two slopes driven from the outcrop, with the view of shipping on a large scale.

2. *General Mining Association, East River of Pictou.*—One of the two new shafts sunk by this company to the dip of the eastern part of their workings, is stated to have reached the main coal at a depth of 840 feet.

This is the deepest shaft in Nova Scotia. The coal penetrated by it is stated to be of good quality, so that in a short time it may be anticipated that the already extensive workings and large produce of this mine will be greatly increased.

3. *Mabou Coal-field.*—Professor Hind has recently reported on the areas of Coal formation rocks between Mabou Harbour and Cape Mabou, referred to at p. 404, *supra.* I am informed by the proprietors of the mine that the Report shows the existence of the ends of two troughs or basins of coal-rocks, exhibiting four groups of beds, in two of which the thickest beds are three feet in thickness respectively. In the third there is a bed thirteen feet in thickness, and in the fourth a bed eight feet in thickness. There is also a layer of cannel coal supposed to be valuable. These, with the Coal measures of Port Hood on the south, and Chimney Corner on the north, show the extension of productive Coal measures at intervals along the western coast of Cape Breton, while it still remains to be ascertained whether other valuable areas do not exist further inland between the shore and the south-west branch of the Margarie River. One peculiarity of the Mabou Coal beds appears to be that their outcrops are unusually near to those of the Lower Carboniferous gypsum.

4. *Merigomish Coal Company, Pictou.*—Reports made by Mr Rutherford, Mr Barnes, and Mr Robb, upon the property of this company to the eastward of the East River of Pictou, show that several workable seams of coal overlie the main seam in this locality: a fact not apparent on the west side of the river. Mr Robb mentions as occurring at a distance of about one-third of a mile horizontally from what is regarded as the outcrop of the main seam, two beds of the thickness of five feet six inches and four feet respectively, and about fifty feet apart vertically. Two other outcrops of the thickness of four feet two inches and three feet six inches, occurring on these areas, are supposed to be a still higher level, though they may possibly be the same. They are associated with a bed of oil-coal or earthy bitumen. The exact thickness of measures thus overlying the main seam is not certainly known, but the facts ascertained would seem to imply an important upward extension of the productive Coal measures, which may greatly add to the value of the areas east of the East River, and, as will appear under the following head, may have a bearing on the probable value of the coal beds lying to the north of the great conglomerate.

5. *Prospects north of New Glasgow.*—The facts above stated for the first time enable me to suggest the probability that valuable discoveries of coal may be made in the extensive district lying between the New Glasgow conglomerate and the harbour of Pictou. If the upper beds above mentioned can be identified with any of those north of New Glasgow, then it is possible that these upper measures may there overlap the lower and more valuable beds, or that the outcrops of these latter may be concealed by faulting and denudation along the line of the conglomerate. The facts at present in my possession are not sufficient to warrant any confident statements on this point; and while it is possible that very limited explorations might suffice to settle the question, it is also possible that great difficulties may be opposed to its satisfactory solution, by the nature of the ground and the relations of the beds. The subject is, however, one deserving of attention, in view of

the new light cast upon it by recent discoveries. I may add, that on the supposition of such northern extension of the productive Coal measures, it may be anticipated that, in accordance with the ideal sections on p. 325, the beds north of the conglomerate will be less massive than those in the southern trough. It must also be observed in connexion with this, that the dips in the northern part of the section (Fig. 136) are somewhat exaggerated.

6. *Victoria Mine, Low Point, Cape Breton.*—This mine, on the south side of Sydney Harbour, presents the first instance in Nova Scotia of coal-mining in areas below the sea; though in the North Sydney Colliery, the main seam has been pursued for some distance below the Harbour. The successful working of this new mine on a large scale will be an interesting feature in our coal-mining, and may lead to other adventures of similar character.

7. *Gold.*—The Report of the Commissioner of Mines shows a total yield for the year ending September 1867 of 27,583 ounces. This amount gives an average of not less than $2, 44c., or about 9s. 9d. sterling per day, for each man employed. It is to be observed in connexion with this, that the methods of extracting the gold, especially when associated with compounds of sulphur and arsenic, are by no means perfect, and that the economy of labour is not so great as it might be in workings on a larger scale. These facts, with the numerous new discoveries reported, confirm the opinion expressed in the text, that the gold-mining of Nova Scotia is capable of profitable extension far beyond its present limits.

In the past year, the Renfrew and Sherbrooke districts have been the first in point of production; and among new localities likely to be of importance, are mentioned, Musquodoboit, the Middle and East Rivers of Sheet Harbour, Mosher's River, Scraggy Lake, Ship Harbour, Upper Stewiacke, and Gold River.

(I.) STRUCTURE OF NORTHERN CAPE BRETON.

I inadvertently omitted in the text to give a summary of the facts in regard to this district ascertained by Mr Campbell in his exploration in 1862, and now quote his general description of the region, which presents several points of interest not previously known.

"To the Gulf of St Lawrence, on its north-west side, it presents a bold front of rounded or conical mountains, united at their base, and appearing like buttresses supporting the table lands of the interior on their flanks. They attain, at some points, an elevation of fifteen hundred feet above the sea level; and their general outline is softened and the landscape rendered beautiful by a dense covering of hardwood forest, by which they are clothed from their base to their summits.

"The greater part of the district is encircled by a rampart of similar mountains, more or less rounded in their contour; and where they happened to be stripped of their covering of forest, by the ravages of fire, they appear as naked cones of crumbly red feldspar rock, which is the prevailing igneous rock of the district, and that from which the principal part of the soil is derived. Hence, no doubt, its extraordinary fertility.

"Viewed from the interior, these mountains appear but little elevated above the general level of the country, which in its main aspects appears comparatively level, although cut by deep valleys and narrow defiles along all its water-courses.

"Wherever bottom-lands or intervale occurs in the valleys, the soil is remarkably rich. This is evident from the heavy growth of healthy-looking timber they produce, consisting principally of maple, birch, beech, and elm, with occasional oak-trees of large size, and well adapted for staves or ship-timber.

"I observed some elm trees as much as four feet diameter, and as straight and tall as any I ever saw in the forests of Canada or the South-western States.

"Most of the steep slopes are also heavily timbered; but on the table-lands the forest is much lighter, and chiefly composed of spruce, fir, and hardwood mixed. The soil generally appears to be good, and comparatively free from stones.

"Considerable tracts of the higher or table-lands are occupied by peat bogs, which will, no doubt, some time hereafter, prove of great value, as they are capable of yielding an unlimited supply of that description of fuel, of the finest quality.

"The surface of these peat-bogs presents the appearance of gently-sloping planes of elliptic form, having deep circular basins at their highest points, full to their brim of clear, icy cold water. These basins are no doubt fed by springs from below, and they appear indispensable to the accumulation of any great depth of peat free from earthy matter.

"The geology of this district bears a very close resemblance to that of the Cobequid Mountains; but the brown feldspar rock, or syenite, which is here the predominant intrusive rock, differs from the syenite in the Cobequid Mountains, in having much less quartz and hornblende in its composition, and it is of a more crumbly and perishable nature. On this account the soil of the district is chiefly composed of it.

"The other intrusive rocks are occasional dikes of porphyry and trap; true granite being very scarce if at all present. The prevailing stratified rocks are the newer clay-slate, or Upper Silurian rocks, and Devonian, or Lower Carboniferous rocks—all metamorphosed to a higher degree, and much more disturbed by igneous masses and dikes, than is observed in any other section of the Province.

"To make out the geological structure of the district on the large scale is not, however, a very difficult task, because extensive sections of the rocks are exposed along the seashore, and in the channels of some of the rivers. The same general arrangement of the strata in parallel folds appears to be the most important feature of its structure; but the strike of the rock inclines more to the northward and southward than I observed anywhere else—being N. 20° E., S. 20° W.; as a general rule the greatest amount of inclination I observed was, N. 15° E., S. 15° W. This brings the strata obliquely to the Gulf Coast line, which has a general course of about N. 40° E., S. 40° W., affording an excellent opportunity for observing the phenomena presented by the different groups along their lines of contact."

(K.)—Fossils of the Palæozoic Rocks.

Classification of Fossil Ferns.—In the text I have not departed fr ordinary arrangement, based on form and venation, though I have with much interest the arrangement of Goeppert and of other G Palæobotanists, based on the fructification as far as known. Since I not, however, apply this system throughout, I have thought it bett to attempt to do so in part; and have merely referred to any tra fructification observed. I had hoped, before publishing the lists con in this work, to have had the benefit of Schimper's revision of the s in his forthcoming "Traité de Palæontologie Végétale;" but this wo not reached me up to the time of writing these lines.

Carboniferous Shells.—Since writing the paragraphs on these, I seen Geinitz's "Memoir on the Carboniferous and Permian of Nebr (Nov., Acta, 1867). Among several identical species and closely forms in that distant region, I observed a shell referred to *Arca s* Schlot, which closely resembles the young of my *Macrodon Har* though probably distinct. Mr Meek, however, in a recent critici Professor Geinitz's paper, identifies this and others of his species with described by American authors.

Silurian Land Plants.—The oldest land plants as yet found in I North America are the Rhizomes of *Psilophyton*, referred to in the t occurring in the Upper Silurian (Lower Helderberg) of Gaspé. I ob however, that Professor Geinitz announces the discovery in Germa a *Lepidodendron* and a *Sternbergia*, or plants resembling these, in believed to be Lower Silurian; and mentions that Barrande has m similar discovery in Bohemia. The specimens would appear not to a very decided character; but the discovery, if confirmed, is very i tant, and would modify the statements in the text as to the oldest Flora.

Fossils from Northern Queen's County.

At page 617, I have mentioned the occurrence of fossils in this di and the probability that rocks newer than the Lower Silurian occur I have recently been enabled, by the kindness of Mr Poole and of Mr of the Department of Mines, Halifax, to examine a small collection of procured by the former gentleman in Brookfield from loose masses. in mineral character and in the contained fossils, which are, however obscure, these specimens resemble the Lower Devonian rocks of Nic and unless they have been drifted from the northward, would tend to co my conjecture of 1855, that "more modern rocks than those of the At coast may be expected to occur" in this district, and, consequently the distribution of the formations in this little known region in the we part of Nova Scotia, may be considerably different from that indicate the map.

(L.) Huronian of New Brunswick.

Mr G. F. Matthew has communicated to me some observations on

rocks near Quaco, showing that the lower part of this series in that region consists of red syenite, felsite, and granulite, not heretofore recognised as sedimentary rocks, and that the full series will be as follows, in descending order:—

Red sediments of comparatively small thickness (No. 5 of Mr Matthew's paper on these rocks).

Dark-coloured trap-slate rocks of great thickness, parted about midway by a rusty-coloured calcareo-arenaceous band charged with iron and manganese (Nos. 2, 3, 4, of paper cited).

Red felspathic rocks of great thickness resting on the Laurentian series.

Mr Matthew suggests the possibility that the red felspathic rocks in the great Lower Silurian band of Northern New Brunswick, marked on the map as eruptive rocks, may be really representatives of these Huronian beds rising from below the Silurian.

Mr Matthew has also recognised in the Huronian of New Brunswick concretions similar to the bodies from the "Lower Taconic" of North Carolina, described by Emmons under the name of *Palæotrochis*.

(M.) Lower Carboniferous of Southern New Brunswick.

Mr G. F. Matthew has communicated to me the following sectional list of the lower Carboniferous beds in Eastern King's County, New Brunswick, in descending order:—

8. Reddish-brown arenaceous shales and red sandstone.
7. Upper conglomerate (Kennebeckasis conglomerate), hard and massive beds.
6. Bright red sandstone and brownish-red shales and sandstones (brine springs rise from these beds).
5. Gray sandstones, flags, and dark gray shales (bituminous), *Cyclopteris Acadica and Lepidodendron corrugatum*.
4. Conglomerate, limestone, gypsum, and dark gray shales (bituminous), *Terebratula sufflata*, etc., *Cyclopteris Acadica*, *Lepidodendron corrugatum*.
3. Lower conglomerate, hard and massive beds.
2. Break in section (probably shales).
1. Basal conglomerate.

These beds vary considerably in tracing their line of outcrop. More especially the lower members thin out toward the west, where the Lower Carboniferous bay terminates between the spurs of older rocks, while in the same part of the area the upper members become increased in thickness. Toward the wider Carboniferous area on the east, some of these upper members are reduced or change in character.

GENERAL INDEX.

THE END.

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JUNCTION OF INTRUSIVE GRANITE AND QUARTZITE IN CLIFF NEAR INDIAN HARBOUR LAKE. (P. 84.)

SUPPLEMENT

TO THE

SECOND EDITION OF

ACADIAN GEOLOG

CONTAINING ADDITIONAL FACTS AS TO THE GEOLOGICAL STRUCTU
FOSSIL REMAINS, AND MINERAL RESOURCES OF

NOVA SCOTIA, NEW BRUNSWICK, AND PRINCE EDWARD ISLAND.

BY

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LIST OF ILLUSTRATIONS.

SUPPLEMENT TO ACADIAN GEOLOGY.

1. INTRODUCTORY.

When in 1868 it became necessary to prepare a second edition of my Acadian Geology, I was surprised to find that the new material on the subject had increased to such an extent as to swell the work to thrice its original bulk, in spite of all my attempts at condensation, and of the omission of many details accumulated in my notes. Now, after the lapse of nine years, in writing a supplementary section to bring the book up to the present state of knowledge, I find myself troubled with a similar superabundance of matter.

It is so far gratifying to me that I have little to retract in the department of theoretical geology. That position of moderate uniformitarianism, with due allowance for intermittent actions which may well be termed cataclysmic, which I have attempted to define in the concluding paragraphs of my book, and which pervades its general tone and the treatment of the varied subjects discussed, may now be considered as the attitude of the great majority of geologists. The battle of the glacialists is perhaps hardly as yet decided, but victory evidently leans to the side of that eclectic doctrine of marine submergence and ice-drift with local land glaciation, which I maintained in 1868, as I had previously done in 1855. The questions relating to the origin of coal and the land conditions of the Carboniferous age, presented in 1868, were answered by the collection of facts shown perhaps more clearly in Nova Scotia than in any other part of the world, and the force of which is now felt everywhere, and supported by evidence abundantly obtained in other countries. The reality and extent of the Devonian flora, though belief in them is still resisted with a pertinacity almost personal by some European botanists, are now generally accepted by geologists. The extension downward of the Palæozoic fauna in America, as far as the Lower Cambrian, and the distinctness of this older fauna from

those which are properly Silurian, due mainly to the lab
Matthew and Hartt, but first brought prominently forward
second edition of this work, has been greatly extended in it
graphical range; and American text-books no longer terminate
zoic life on the horizon of the Potsdam. The still greater fact
extension of animal life backward into the Eozoic age, thoug
denied by some, is steadily advancing in acceptance.

My own work in the geology of the Acadian Provinces, since
has necessarily been limited by distance and by other occupa
It includes—(1.) A geological reconnaissance of Prince Ed
Island,* in which I was assisted by Dr B. J. Harrington, an
which the subdivisions of the Trias in that island and the exist
and distribution in it of rocks of the Upper Coal formation
first ascertained; (2.) A detailed Report on the Flora of the U
Silurian and Devonian Rocks, published by the Geological Surve
Canada in 1871, in which the fossil plants of the New Bruns
Devonian were first adequately figured and described, and t
geological relations discussed; (3.) A similar Report on the F
Plants of the Lower Carboniferous and Millstone-grit, in which t
plants and the beds containing them were correlated with thos
other parts of America and in Europe; (4.) A Revision of the P
pliocene Geology, in my "Notes on the Post-pliocene of Canada
(5.) Memoirs on the Relation of the Upper Coal Measures of N
Scotia to the Permian; ‡ On the Impressions and Footprints
Animals in the Carboniferous Rocks; § On *Sigillaria*, *Calamites*,
Lepidodendron; ‖ On New Carboniferous Batrachians;¶ and on
Geological Relations of the Iron Ore Deposits.** I have besi
given assistance in the determination of fossils and in other ways
most of the other workers who have been in the field, so that
connection with Acadian geology has been continuously maintai
I may add that, in connection with the preparation of this sup
ment, I have twice visited Nova Scotia, and re-examined district
special interest, and that I have in many instances been delighted
find how much, previously inaccessible or obscure, had been
closed by new lines of railway, mining operations, and other chan

The extension of the Geological Survey of the Dominion to
Acadian Provinces has brought into the field a host of work
armed with those advantages of ample time and public funds w

* Report on Geology of P. E. I., 1871.
† Montreal, 1872.
‡ Journal, Geological Society, Aug. 1874.
§ Am. Jl. Science, January
‖ Journal, Geol. Socy., May 1873.
¶ Am. Jl. Science, Dec. 18
** Proceedings Am. Association, 1874.

are not accorded to those who labour for the mere love of science, and thus an immense amount of details not previously accessible have been accumulated. In this Supplement I shall have to summarise or refer to Reports by Sir W. E. Logan, Mr Selwyn, Dr Hunt, Professor Bailey, Mr Matthew, Mr Robb, Mr M'Owat, Mr Hartley, Mr Scott Barlow, Mr Fletcher, and Mr Ells, embracing in all a volume of matter much greater than that of my book. In addition to this, local geologists and collectors have not been idle, and more especially a number of important papers and reports have been published by Mr Poole, Professor Hind, Dr Honeyman, Mr Matthew, Mr Gilpin, Professor How, Professor Chapman, Mr Paisley, and others.

In dealing with this great mass of matter, I shall first notice the modifications required in the Geological Map, and shall then refer to the several formations in succession, limiting myself under each to those points which seem most important either in local or general geology.

Finding by experience that the general arrangement of my book, whereby the notices of fossils and of useful minerals were distributed under the heads of the districts in which they principally occur, has caused some difficulty in reference, and has perhaps led to the overlooking of important facts by readers, I shall add a classified table of contents which may remove this inconvenience.

2. THE GEOLOGICAL MAP.

In the second edition of this work it was stated that the map, though greatly improved, "is to be regarded as merely a rude approximation to the truth;" and though more detailed and accurate maps of certain districts have since been published, so much remains to be done, and so much uncertainty exists, that I have thought it best not to alter the colouring in this edition, but merely to note the changes which up to the present time would seem to be indicated by new facts.

In the map, the limits of the Triassic and Carboniferous formations, as they could be broadly indicated by tracing these formations on a number of lines of section up to their borders, were taken as the dominant boundaries, and little attempt was made to indicate the subdivisions of the older Metamorphic series. Even this much involved a large amount of labour, in time snatched from the intervals of other employments, and was necessarily very imperfectly done, yet these general limits, as fixed by me in 1868, may be said still to remain, the principal exceptions being the extension of the Upper Coal formation along the N.-W. coast of Prince Edward Island,

and to Governor's Island and Gallas Point in Hillsborough Ba error of the colourist, whereby the tint of the Lower Siluria extended over a part of the Carboniferous near Bathurst, in Brunswick, and some local corrections in Antigonish County and Breton.

The older formations of Nova Scotia and New Brunswick hav along been liable to the same difficulties which have made similar rocks of New England the stumbling-block of geolog Originally very different from the sediments of equivalent ag that "New York Series" which has been usually regarded as typ intermixed with anomalous and irregular volcanic beds, much turbed and profoundly changed by metamorphic action, and for most part covered with soil or buried in forests, they presented d culties altogether insuperable in 1868, and which even yet have b very partially removed. I was, however, able, with the aid of New Brunswick geologists, roughly to arrange them under six tinct colours. These were, with their respective numbers, (Devonian; (5.) Upper Silurian; (6.) Lower Silurian, includ Cambrian; (7.) Huronian; (8.) Laurentian; (10.) Granite, Syenite,

In Nova Scotia, the only district coloured as Devonian is that the south side of the Annapolis Valley, or the Nictaux and Bear Ri formation. The fossils of this are of Oriskany age, and would n by some geologists, be regarded as Upper Silurian rather than Lower Devonian. The only other area which I could indicate in t province is a small patch of quartzose rock, holding obscure fo plants, which projects through the Carboniferous between the E and Middle Rivers of Pictou, and which is delineated on Sir Willi Logan's detailed map of that district, but is too small to appear my map. In New Brunswick the Devonian area requires to diminished by the removal of the large patch between Quaco Shepody Bay, which consists of altered rocks of much older da a remark which also applies to the smaller areas indicated on map immediately west of St John. On the other hand, considera portions of the hard, slaty, and arenaceous rocks rising from bene the Carboniferous on its south-western border, and mapped as Lo Silurian, have been ascertained by Messrs Bailey and Matthew to Devonian.

Mr R. Chalmers, who is engaged in preparing a geological ma Restigouche County, reminds me that a limited exposure of sands and conglomerate near Dalhousie, holding obscure fossil pl and referred by the Geological Survey to the Gaspé sandstones,*

* Report of Progress, 1863.

been omitted on my map. I have also found that these Devonian rocks, represented by red and gray sandstones with characteristic fossils, come in, in great force, near Casaupscal, on the east side of the Metapedia, and just on the northern limit of the map.

Rocks characterized by fossils of Upper Silurian age skirt the southern side of the great crystalline belt extending south-westward from Bathurst in New Brunswick, and doubling round the south-west end of the Carboniferous area of that province. They are coloured in the map as Lower Silurian, and by an error of the colourist are extended over a part of the Carboniferous area near Bathurst. On the other hand, a portion of the Upper Silurian area near the lower part of the St John River, and constituting the Kingston group, is regarded as in part at least occupied with older rocks. In Nova Scotia, rocks of Upper Silurian age skirt the Cobequid Hills from Wentworth to New Annan and Earlton, and reappear on the East River of Pictou, extending thence to Arisaig and Lochaber Lake. To the westward they reappear and cover considerable areas at New Canaan and elsewhere in King's County, and also in Northern Queen's County. All these districts are indicated in my map by the proper colour, but I have included with them large areas occupied by non-fossiliferous rocks of various mineral characters, and which subsequent observers have been disposed to assign to a much older date. The reasons of this will be discussed farther on.* In the meantime, I may state that there are some grounds for the belief that considerable areas marked as Upper Silurian in Nova Scotia and Cape Breton may prove to be Lower Silurian, or even older, and that if we confine the colour to those areas in which fossils of Upper Silurian age have been actually recognised, its breadth will be restricted, both in the east and west, to certain narrow bands in the districts so coloured on the present maps.

Unfortunately, with one possible exception in Cape Breton, no distinct fauna of the typical Lower Silurian age has yet been recognised in the Acadian Provinces. A few Graptolites found by Mr. Robb in the great belt north of the crystalline area already referred to in New Brunswick, would seem to indicate equivalents of the Quebec group. In Nova Scotia there are stratigraphical reasons to suppose that portions, at least, of the remarkable semi-volcanic or ash rocks, which underlie the beds with Upper Silurian fossils, may be of this age.

With reference to the great belt of Lower Silurian constituting the Gold series on the coast of Nova Scotia, its age was held by me in

* Under headings "Lower Silurian" and "Cambrian."

1868 to be properly Cambrian, though in deference to the classification of Murchison—then almost universally adopted—it was mapped as Silurian. Such fossils as have since been found in it by Selwyn, Hind, and myself, and those of its extensions in Newfoundland and New England, would seem to confirm this conclusion. Mr Selwyn has, however, found that in the west the granite and gneissose areas should be much extended, and Prof. Hind proposes to separate portions of the gneissose rocks as Laurentian and Huronian. These points also will be discussed in the sequel.

The above corrections in the Upper and Lower Silurian districts of the map may be summarised as follows:—If the reader will consider the blue tint indicating Upper Silurian to cover Lower Silurian as well, and the purple tint representing Lower Silurian to indicate Cambrian, the map will be approximately correct, with the exceptions already referred to in New Brunswick, and some areas in Northern Cape Breton and the western part of Nova Scotia, to be subsequently referred to.

The Huronian rocks of New Brunswick, as marked on the map, are still recognised as such; but it has been proposed to join to them several other groups, on the ground of mineral character principally. As this conclusion is still under discussion, I defer its consideration till farther on.

Messrs Bailey and Matthew have introduced several new areas of Laurentian rocks in their recent maps of Southern New Brunswick; and large areas in Southern and Eastern Nova Scotia and Cape Breton have been referred to this age by local geologists and officers of the Survey, whose views on this subject, however, I do not regard as established by my own observations. They will be referred to on subsequent pages.

The little island of Grand Manan, at the mouth of the Bay of Fundy, has fared very badly in my map. I have not myself visited it, and it seems that the information accessible to me in 1868, and given in the appendix to my book, had led to very incorrect inferences on my part. From recent reports by Prof. Bailey and Mr Matthew, and by Prof. Chapman, it seems that the western half of the island consists of Triassic trap resting on tufa and red sandstone, the eastern half of old crystalline rocks, possibly Laurentian.

The Magdalen Islands, though politically connected with the Province of Quebec, fall within the map of Acadia. They are represented as Carboniferous; and I can now confirm this from the inspection of an interesting series of specimens collected by the Hon. Judge M'Cord. These show that the rocks of these islands belong

to the Lower Carboniferous or Gypsiferous series, and they no doubt form a portion of a rim of these rocks, limiting the Carboniferous area of the Acadian Bay, and extending from Northern Cape Breton toward the Baie des Chaleurs.

The south-western corner of Newfoundland, extending into the map, includes part of the Coal-field of St George's Bay, and of a Laurentian area which bounds it on the east. These formations have recently been described by Murray in his Reports on the Geology of Newfoundland, and have been represented on his beautiful map of the island. Specimens in my possession show that the Carboniferous limestone of Newfoundland includes abundance of the characteristic fossils of that formation, and that its fossil plants are principally such as in Nova Scotia occur in the Millstone-grit.*

3. THE MODERN PERIOD.

Changes of Level.—In the surveys for the Baie Verte Canal, made by Mr Page under authority of the Dominion Government, I find it stated in the Report of Mr Baillargé, that between the Missaquash River and Cumberland Creek, to the north of the point where I observed the submarine forest of Fort Lawrence,† stumps of trees were seen rooted in earth for more than half a mile along the shore, and extending from low-water mark to the bank. They are stated to be from 32·8 feet to 22·3 feet below the level of the highest tides. The surveyors recognised spruce, beech, pine, and tamarac, all in a fair state of preservation, and rooted in a vegetable mould underlaid by a sandy subsoil. In my Report on Prince Edward Island I have noticed evidence of similar modern subsidence, though to a less amount. These facts place themselves in connection with the probability that in America, as in Europe, a period of continental elevation succeeded the great Post-pliocene subsidence, and has been followed by a depression in more modern times. This consideration seems to account for some otherwise anomalous facts in connexion with the distribution of modern marine animals. I referred to these points in my annual address to the Natural History Society of Montreal in 1874, and may here repeat the substance of what was then said.

The Acadian Bay in relation to Modern Subsidence.—If we draw a straight line from the northern end of Cape Breton through the Magdalen Islands to the mouth of the Bay des Chaleurs, we have

* Report on Fossil Plants of L. Carboniferous and Millstone-grit, 1873.

† Ac. Geol., p. 29.

to the southward an extensive semicircular bay, 200 miles diameter, which we may call the great *Acadian Bay,* and on t north the larger and deeper triangular area of the Gulf of St La rence. This Acadian Bay is a sort of gigantic warm-water aquariu sheltered, except in a few isolated banks which have been point out by Mr Whiteaves, from the cold waters of the gulf, and whic the bather feels quite warm in comparison with the frigid and oft not very limpid liquid with which we are fain to be content in th Lower St Lawrence. It also affords to the more delicate marin animals a more congenial habitat than they can find in the Bay c Fundy, or even on the coast of Maine, unless in a few sheltere spots, some of which have been explored by Professor Verrill. I is true that in winter the whole Acadian Bay is encumbered with floating ice, partly produced on its own shores and partly drifted from the north; but in summer the action of the sun upon its surface, the warm air flowing over it from the neighbouring land, and the ocean water brought in by the Strait of Canseau, rapidly raise its temperature, and it retains this elevated temperature till late in autumn. Hence the character of its fauna, which is indicated by the fact, that many species of molluscs whose headquarters are south of Cape Cod flourish and abound in its waters. Among these are the common oyster, which is especially abundant on the coasts of Prince Edward Island and Northern New Brunswick, the Quahog or Wampum shell, the *Petricola pholadiformis,* which, along with *Zirfæa crispata,* burrows everywhere in the soft sandstones and shales; the beautiful *Modiola plicatula* forming dense mussel-banks in the sheltered coves and estuaries; *Cytherea* (*Callista*) *convexa; Cochlodesma leana* and *Cummingia tellinoides; Crepidula fornicata,* the slipper-limpet, and its variety *unguiformis,* swarming especially in the oyster-beds; *Nassa obsoleta* and *Buccinum cinereum,* with many others of similar southern distribution. Nor is the fauna so very meagre as might be supposed. My own collections from Northumberland Strait include about fifty species of molluscs, and some not possessed by me have been found by Mr Whiteaves. Some of these, it is true, are northern forms, but the majority are of New England species.

The causes of this exceptional condition of things in the Acadian Bay carry us far back in geological time. The area now constituting the Gulf of St Lawrence seems to have been exempt from the great movements of plication and elevation which produced the hilly and metamorphic ridges of the east coast of America. These all die out and disappear as they approach its southern shore. The tranquil and gradual passage from the Lower to the Upper Silurian

ascertained by Billings in the rocks of Anticosti, and unique in North America, furnishes an excellent illustration of this. In the Carboniferous period the Gulf of St Lawrence was a sea area as now, but with wider limits, and at that time its southern part was much filled up with sandy and muddy detritus, and its margins were invaded by beds and dykes of trappean rocks. In the Triassic age the red sandstones of that period were extensively deposited in the Acadian Bay, and in part have been raised out of the water in Prince Edward Island, while the whole bay was shallowed and partially separated from the remainder of the gulf by the elevation of ridges of Lower Carboniferous rocks across its mouth. In the Post-pliocene period, that which immediately precedes our own modern age, as I have elsewhere shown,* there was great subsidence of this region, accompanied by a cold climate, and boulders of Laurentian rocks were drifted from Labrador and deposited on Prince Edward Island and Nova Scotia, while the southern currents flowing up what is now the Bay of Fundy, drifted stones from the hills of New Brunswick to Prince Edward Island. At this time the Acadian Bay enjoyed no exemption from the general cold, for at Campbellton, in Prince Edward Island, and near Bathurst, in New Brunswick, we find in the clays and gravels the northern shells generally characteristic of the Post-pliocene,—though perhaps the lists given by Mr Matthew for St John, and by Mr Paisley for the vicinity of Bathurst, may be held to show some slight mitigation of the Arctic conditions as compared with the typical deposits in the St Lawrence valley. Since that time the land has gradually been raised out of the waters, and with this elevation the southern or Acadian fauna has crept northward and established itself around Prince Edward Island, as the Acadian Bay attained its present form and conditions. But how is it that this fauna is now isolated, and that intervening colder waters separate it from that of Southern New England? Verrill regards this colony of the Acadian Bay as indicating a warmer climate intervening between the cold Post-pliocene period and the present, and he seems to think that this may either have been coincident with a lower level of the land sufficient to establish a shallow-water channel connecting the Bay of Fundy with the Gulf, or with a higher level raising many of the banks on the coast of Nova Scotia out of water. Geological facts, which I have illustrated in Acadian Geology, indicate the latter as the probable cause. We know that the eastern coast of America has in modern times been gradually subsiding. Further, the remarkable submarine forests in the Bay of Fundy show that

* Notes on Post-pliocene of Canada, Canadian Naturalist, 1872.

within a time not sufficient to produce the decay of pine woo depression has taken place to the extent of at least 40 fee probably to 60 feet or more. We have thus direct geo evidence of a former higher condition of the land, which may, at its maximum, have greatly exceeded that above indicated, we cannot trace the submarine forests as far below the sea-le they actually extend. The effect of such an elevation of the would be not only a general shallowing of the water in the B Fundy and the Acadian Bay, and an elevation of its temper both by this and by the greater amount of neighbouring land, bu Professor Verrill well states, it would also raise the banks of Nova Scotia coast, and extending south from Newfoundland, so throw the Arctic current further from the shore and warm the w along the coasts of Nova Scotia and Northern New England. these circumstances the marine animals of Southern New Engl might readily extend themselves all around the coasts of Nova Sc and Cape Breton, and occupy the Acadian Bay. The modern s sidence of the land would produce a relapse towards the Glacial the Arctic currents would be allowed to cleave more closely to coast, and the inhabitants of the Acadian Bay would gradu become isolated, while the northern animals of Labrador would w their way southward.

Various modern indications point to the same conclusions. Ve has described little colonies of southern species still surviving on coast of Maine. There are also dead shells of these species in m banks, in places where they are now extinct. He also states that remains in shell-heaps left by the Indians indicate that even wi the period of their occupancy some of these species existed in pl where they are not now found. Willis has catalogued some of tl species from the deep bays and inlets on the Atlantic coast of N Scotia, and has shown that some of them still exist on the S Island banks.*

Whiteaves finds in the Bradelle and Orphan bank littoral spe remote from the present shores, and indicating a time when tl banks were islands, which have been submerged by subside aided no doubt by the action of the waves.

It would thus appear that the colonization of the Acadian with southern forms belongs to the modern period, but that it already passed its culmination; and the recent subsidence of the has no doubt limited the range of these animals, and is probably favouring the gradual inroads of the Arctic fauna from the n

* Ac. Geol., chap. iii. p. 37.

which, should this subsidence go on, will creep slowly back to reoccupy the ground which it once held in the Post-pliocene time.

Such peculiarities of distribution serve to show the effects of even comparatively small changes of level upon climate, and upon the distribution of life, and to confirm the same lesson of caution in our interpretation of local diversities of fossils, which geologists have been lately learning from the distribution of cold and warm currents in the Atlantic. Another lesson which they teach is the wonderful fixity of species. Continents rise and sink, climates change, islands are devoured by the sea or restored again from its depths, marine animals are locally exterminated, and are enabled in the course of long ages to regain their lost abodes, yet they remain ever the same, and even in their varietal forms perfectly resemble those remote ancestors which are separated from them by a vast lapse of ages and by many physical revolutions. This truth, which I have already deduced from the Post-pliocene fauna of the St Lawrence Valley, is equally taught by the molluscs of the Acadian Bay, and by their Arctic relatives returning after long absence to claim their old homes.

Oyster-beds or Mussel-beds.—In the bays and estuaries of Prince Edward Island, and of the northern coast of Nova Scotia, vast accumulations of the shells of the American oyster, *Ostrea Virginiana*, and those of the mussel, *Mytilus edulis*, have taken place, and must be deposits of the modern period succeeding the Post-pliocene. I have been informed by Mr W. H. Pope, who has given much attention to this subject, that some of these beds are fifteen feet or more in thickness. They consist of dead shells, and in many places no living shells occur even at the surface, the animals having been killed by the gradual approach of the beds to the surface of the water, exposing them to the action of the frost and ice and to invasion of sandy sediment. These beds of dead oyster and mussel shells, with the mud filling the interstices, constitute one of the most valuable deposits on the island. Under the name of "Mussel Mud" this material is taken up in great quantity by ingenious dredging machines, worked from rafts in summer or from the ice in winter, and is applied as a manure to the soil with the most excellent effects. It supplies lime and organic matter, besides small quantities of phosphates and alkalies.

The shells in these old beds are all of the long narrow form (*O. Virginiana*), and Mr Pope informs me that the round form (*O. borealis*) occurs at the surface in many places where the long narrow form is found only a few inches below. It also appears that the modern oysters procured in the upper parts of the rivers and on

muddy bottom tend to the long form, while those in more salt and on hard bottom are round.

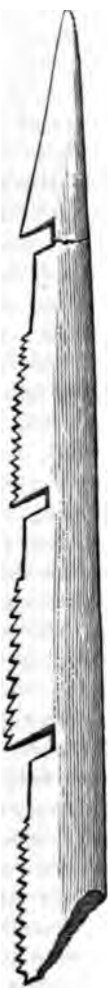
Sand-Hills or Dunes of Prince Edward Island.—These mou drifted sand are extensively developed along the outer or nortl shore, where they stretch in long lines across the bays and para the coast. In all they extend in length about 45 miles, and are times more than 40 feet high. Though usually held together b roots of coarse grasses, they are liable to frequent changes, whic much promoted by the cropping of the grass by the cattle, or by artificial or accidental breaking of the surface. At St Peter's I sa old entrance, used in the early French times, quite filled up witl blown sand; and I was told that a hill, 40 feet high, had been rem within a few years, and had disclosed the remains of an old bl smith's forge under its base. The sand in these hills is derived the waste of the red sandstones; and, when left dry by the tid blown up by the wind. The attrition to which it has been subje has removed the coating of red oxide of iron from the siliceous gr of sand, so that, though derived from red rocks, these sands are ne white. Where the sand-hills run along the coast, a long nar channel often occurs between them and the shore, and they o block up streams, forming lagoons, in which deposits very diffe from those of the open gulf are produced.

Shore Ridges in Prince Edward Island.—Mr Pope kindly poi out to me, on a creek near Grand River and on Ives Creek, mounds known locally as "shooting dykes," in allusion to their by sportsmen as a shelter in duck-shooting. These are somew regular banks or dykes of soil fringing the creeks, and having alr the appearance of artificial earthworks, which they have indeed l supposed to be. Some of them are 6 feet in height and 10 feet wid base. I believe them to be of the same nature with the Lake Ri of Nova Scotia described in Chapter III., p. 35, and that they l been produced by the expansion or driftage of the ice which form the creeks in winter. They constitute a sort of "moraine" dep which, on a larger scale and in a more hilly country, might rea be mistaken for the work of glaciers. Those that we saw were tirely composed of soil intermixed with vegetable matter. Son them showed evidence of formation by successive increment material. Their steepest sides were next the land, and they highest opposite the most exposed and widest portions of the cre

Micmac Remains.—Since the publication of Acadian Geo some attention has been given by Dr Gilpin, Mr Gossip, Dr P son, and others to the prehistoric antiquities of Nova Scotia

several interesting papers have appeared in the Transactions of the Nova Scotia Institute. The numerous "Kjökkenmödding" or piles of culinary debris occurring on the coast have been in part explored, and have been found to contain shells of most of the edible molluscs of the coast and bones of the ordinary modern mammals, birds, and fishes, with stone implements and fragments of rude pottery. All these remains are probably referable to the Micmacs; and nothing definite seems to have been discovered as to any previous race, though Micmac tradition, according to Mr Rand, points to a previous people, probably of the Tinné or Chippewyan stock, and allied to the Red Indians of Newfoundland.

Fig. 1.



Chips of stone found at old arrow-making places in Lunenburg, Pictou, and Prince Edward Island, show that the Micmacs had ransacked all sorts of repositories of useful stones, and were in the habit of availing themselves of a great variety of agates, jaspers, quartzites, and hard slates in the manufacture of chipped weapons, while diorite and hard quartzose slate were favourite materials for polished tools. A bone fish-spear or harpoon, found by Dr Patterson at Merigomish, is the only implement of this kind I have seen (Fig. 1). It is ingeniously barbed, much after the manner of the modern Esquimaux harpoons, or some of those belonging to prehistoric Europe. All the earthenware that I have seen is of rude manufacture, and the patterns less tasteful than in those of the inland agricultural nations. The few tobacco-pipes found are similar to those of the other Algonquin tribes. Tobacco, according to Lescarbot, was used by the Micmacs, but they did not cultivate it, obtaining their supplies from tribes further to the south, and in default of such supplies, using, like other northern tribes, native narcotic herbs. The modern Micmacs sometimes extemporise a tobacco-pipe in the form of an ingeniously twisted cone of birch bark. If this habit existed among their ancestors, it would account for the comparative paucity of stone pipes.

4. THE POST-PLIOCENE.

Climate.—At p. 78, Chap. V., I have remarked on the fact that while the climate of Western Europe in the Pleistocene period, as

indicated by fossil shells, was much more severe than at present, comparatively little change has occurred in our American seas. I have more fully illustrated this difference in my Notes on the Post-pliocene Geology of Canada, and have shown that it is to be explained principally by the distribution of the marine currents. Crosskey and others have recently directed attention to it in England, but it receives less attention than it deserves, in consequence of the tendency to seek for causes of an extreme and general glaciation of the northern hemisphere. It should, however, be regarded as of the utmost importance as indicating the value of that different distribution of land and water so much insisted on by Sir C. Lyell as a cause of change of climate, and to which I still think, as in 1868, that the cold of the glacial period is mainly referable.

In any case, I still fail to find, either in the Acadian Provinces or in Canada proper, any indication of a great continental glacier. What I do find is the evidence of great depression of the land, accompanied with a reduction of the mean temperature to such an extent that the hills remaining above water were occupied with local glaciers, and formed areas of denudation, while the lower lands, traversed by northern currents of ice-cold water, bore floating ice throughout the year, and this was steadily pushed by the lower currents from the north-east; while in periods of extreme submergence there was a drift, perhaps caused by prevailing winds, from the north-west. In these circumstances the boulder clay and the lower part of the Leda clay were formed, and are consequently non-fossiliferous, or hold only a few Arctic shells. Re-elevation brought shallowness, and consequently warmer water, and eventually land surfaces, and introduced the modern climate.

Whatever the cause of this submergence, the fact of its occurrence is proved by the marine clays and the high-level sea-beaches. Mr Richardson of the Geological Survey has found these terraces 1225 feet above the sea on the coast of Newfoundland, and the evidence of travelled stones would take the sea to the tops of the highest hills in Eastern America, 6000 feet above the sea. The drift phenomena of the western plains and the Rocky Mountains imply subsidence there to the extent of at least 4400 ft.* Now, the existing climates of the North Atlantic, as compared with those of the Post-pliocene, point precisely to the natural effects of such a submergence, while the action of local glaciers, of pack and pan ice, and of drifting bergs, as now actually observed, would, if intensified, as they must have been by the causes supposed, give all the observed effects of glaciation. There is there-

* G. M. Dawson, Report on 49th Parallel.

fore no geological necessity to appeal to the varying eccentricity of the earth's orbit and the precession of the equinoxes, or to an imagined change of the earth's axis of rotation, or of the obliquity of the ecliptic, or of the energy of the sun's radiation. If these, or any of them, can be proved on other grounds, geologists may fairly be called on to allow for their influence; but there is no geological necessity for them, other than the exigencies of an imaginary period or succession of periods of continental glaciation, of which unquestionably there is no geological evidence in Eastern America. For facts in support of this view, I may refer not only to the chapter on Acadian Geology on this subject, but to my subsequently published Notes on the Post-pliocene of Canada. It would occupy too much space to repeat them here, except in so far as they may come up under subsequent heads.

Boulder Clay and Glacial Erosion.—From the views as to these subjects, given fully in Chapter V., I have seen as yet no cause to recede. Since they were published, the doctrine of continental glaciers has waxed and waned, and the greater number of the ablest workers in this field are now not very remote from the position which I occupied in 1868. Quite recently, the discovery by the "Challenger" soundings that a deposit of stones and mud is now rapidly forming in the South Pacific by the melting of ice, the observations on the action of pack ice by the recent Arctic Expedition, and the exposition of the action of pack ice on the coast of Newfoundland, given by Professor Milne in the Geological Magazine for 1876, have strengthened very much the position of those who hold that the glacial drift and striation have been mainly due to floating sheets and bergs, at a time when the northern seas were much more extensively occupied with them than at present.* I have very fully discussed this subject in my Notes on the Post-pliocene Geology of Canada, already referred to, and shall merely quote here a passage on a subject referred to in Chapter V., and on which more complete information has since been obtained. I refer to the erosion of the basins of the great American lakes :—

"These have been cut out of the softer members of the Silurian and Devonian formations; but the mode of this excavation has been regarded as very mysterious; and, like other mysteries, has been referred to glaciers. Its real cause was obviously the flowing of cold currents over the American land during its submergence. The lake-basins are thus of the same nature with the deep hollows intervening

* See also Professor Hind's paper in the Canadian Naturalist, 1877, referred to further on.

between the banks cast up by the Arctic currents of the present American coast, and like those deep channels of the Arctic current in the Atlantic recently explored by Dr Carpenter. Their arrangement geographically, as well as their geological relations, correspond with this view."

"Another consideration with regard to the great lakes deserves notice. Dr Hunt and Dr Newberry have collected many facts to show that the lake basins are connected with one another and with the sea by deep channels now filled up with drift deposits. It is therefore possible that much of the erosion of these basins may have occurred before the advent of the glacial period, in the Pliocene age, when the American continent was at a higher level than at present. Dr Newberry has given in the Report of the Geology of Ohio a large collection of facts ascertained by boring or otherwise, which go far to show, that were the old channels cleared of drift and the continent slightly elevated, the great lakes would be drained into each other and into the ocean by the valleys of the Hudson and the Mississippi without any rock-cutting, and if the barrier of the Thousand Islands were then somewhat higher, the St Lawrence valley might have been cut off from the basin of the great lakes."

"It would thus appear that in the Pliocene period the basin of the lakes may have been a great plain with free drainage to the sea. Instead of being afterwards occupied by a glacier, this plain and its channels leading to the ocean were filled with clay at the beginning of the Post-pliocene subsidence; and at a later date the mud was again swept out from those places where the Arctic current could most powerfully act on it."

In Chapter V. I have illustrated the power of coast ice in moving boulders. Since this was written I have had the opportunity of witnessing similar effects on a much grander scale in the estuary of the River St Lawrence, and Professor Hind has described these effects, as well as extensive polishing, on the coast of Labrador. He says,* with reference to the great sheets of "pan ice:"—

"'Pan' ice is derived from bay ice, floes, and coast ice, varying from 5 to 10 or 12 feet in thickness, all of which are broken up during spring storms. When the disruption of the ice sheet which seals the fiords, the island zone, and the sea itself for many miles outside, continuously, is effected in June, the resulting 'pans,' as the fishermen term them, vary in size from a few square yards to many acres in extent. The uniform and unbroken mass of ice in the winter

* Paper read before the Natural History Society of Montreal, 1877, Canada Naturalist, vol. viii.

months has no lateral motion; it rises and falls with the tide, but is unaffected by winds until the warmth of spring softens its hold on the islands to which it is keyed. When the pans are pressed on the coast by winds, they accommodate themselves to all the sinuosities of the shore line, and being pushed by the unfailing Arctic current, which brings down a constant supply of floe ice, the pans rise over all the low-lying parts of the islands, grinding and polishing exposed shores, and rasping those that are steep-to. The pans are shoved over the flat surfaces of the islands, and remove with irresistible force every ob.tacle which opposes their thrust, for the attacks are constantly renewed by the ceaseless ice-stream from the north-west, and this goes on uninterruptedly for a month or more. Sometimes a change in the wind brings the endless sheet back again, and it is the middle of July before some of the fiords are clear of ice. Hence boulders, shingle, and beaches are rarely seen except in sheltered nooks and coves, and the masses, *pushed* or torn from those surfaces where cleavage offers a chance of disruption, are urged into the sea and rounded into boulder form by the rasping and polishing pans."

"Here too goes on the process, subsequently referred to, of manufacturing boulder clay, for the deep hollows and ravines at present under the sea—the records of former glacial work—are being filled with clay, sand, unworn and worn rock fragments, producing a counterpart of some varieties of boulder clay."

"But this is not all of the work of pan ice. The bottom of the sea, to the depth of 12 or 15 feet, and at all less depths, is smoothed and planed by the drifting masses when they pile one on the other, and at depths less than 8 feet when the pans are driven before the wind or carried by the currents. In sailing from Aillik to Nain or to Cape Mugford, the fishermen send a man aloft to look out for "White Rocks." These are prominences or swells in the general level of the sea-bottom among the islands, from which every particle of sea-weed has been removed by pan ice."

"During a period of subsidence, the blocks of stone, boulders, mud, and sand, pushed to and fro on the shallow sea-bottom by pan ice, ultimately accumulate in hollows and ravines below its action; and when the debris is pushed into profound submarine valleys, such as exist on the Labrador coast (being probably due to former glacial action), the mass will resemble boulder clays, and in a sinking marine area it will accumulate to a great thickness; in a rising area it would be liable to be remodelled by the action of the waves except in the case of very deep valleys. There are not many known narrow and profound submarine valleys on the north-eastern coast of Labra-

dor, but those which are known offer precisely the conditions r
for the accumulation of boulder clays or drift by the action
ice."

"The seaward extension of Uksuktak Fiord, which lies a li
the south of Hopedale, affords an apt illustration. Comm
Maxwell's soundings show a profound submarine ravine be
clusters of islands for upwards of eight miles, in which the
reaches 124, 126, 123, 106, and 130 fathoms. Between the is
of Niatak and Paul, near Nain, the lead shows 71 fathoms.
evident that the material torn from the surrounding islands by
ice, and pushed along the bottom of the sea into these profound
marine valleys during a period of general submergence, will be
tected from the action of the waves, and the loose blocks and boul
will have a forced arrangement in the mud, as if they had l
pushed over a bank, and thus produce the irregular dispositio
frequently seen in boulder clay deposits. In such narrow and
found valleys as those instanced, the accumulation of boulder
probably goes on at the present time, and may continue durin
period of elevation, until large portions of the drift are raised ab
the sea-level and beyond the influence of the waves, which will att
only its sea front. But the agent which gives rise to this het
geneous mass is pan-ice, and the formation of boulder clay is
probably a part of its work over a vast area on the Labrador coas
the present day, throughout the labyrinth of islands which fringe
coast to a depth of 20 miles seawards. If one examines the l
deposits of boulder clay in various parts of Nova Scotia, with
worn gneissic rocks close at hand, or underlying the clays, the c
clusion that pan ice has been instrumental in accumulating man
those deposits is irresistible."

Post-pliocene of Prince Edward Island.—On this I had li
information in 1868, but have since studied it in some detail.

The Triassic and Upper Carboniferous rocks of this island con
almost entirely of red sandstones, and the country is low and un
lating, its highest eminences not exceeding 400 feet. The preva
Post-pliocene deposit is a boulder clay, or in some places bou
loam, composed of red sand and clay derived from the waste of
red sandstones. This is filled with boulders of red sandstone der
from the harder beds. They are more or less rounded, often glaci
with striæ in the direction of their longer axis, and somet
polished in a remarkable manner, when the softness and c
character of the rock are considered. This polishing must
been effected by rubbing with the sand and loam in which the

embedded. These boulders are not usually large, though some were seen as much as five feet in length. The boulders in this deposit are almost universally of the native rock, and must have been produced by the grinding of ice on the outcrops of the harder beds. In the eastern and middle portion of the island, only these native rocks were seen in the clay, with the exception of pebbles of quartzite, which may have been derived from the Triassic conglomerates. At Campbellton, in the western part of the island, I observed a bed of boulder clay filled with boulders of metamorphic rocks similar to those of the mainland of New Brunswick.

Striæ were seen only in one place on the north-eastern coast and at another on the south-western. In the former case their direction was nearly S.W. and N.E. In the latter it was S. 70° E.

No marine remains were observed in the boulder clay; but at Campbellton, above the boulder clay already mentioned, there is a limited area occupied with beds of stratified sand and gravel, at an elevation of about 50 feet above the sea, and in one of the beds there are shells of *Tellina Grœnlandica.*

On the surface of the country, more especially in the western part of the island, there are numerous travelled boulders, sometimes of considerable size. As these do not appear in situ in the boulder clay, they may be supposed to belong to a second or newer boulder drift, similar to that which we find to be connected with the Saxicava sand in Canada. These boulders being of rocks foreign to Prince Edward Island, the question of their source becomes an interesting one. With reference to this, it may be stated in general terms that the majority are granite, syenite, diorite, felsite, porphyry, quartzite, and coarse slates, all identical in mineral character with those which occur in the metamorphic districts of Nova Scotia and New Brunswick, at distances of from 50 to 200 miles to the south and south-west, though some of them may have been derived from Cape Breton on the east. It is further to be observed, that these boulders are most abundant and the evidences of denudation of the Trias greatest in that part of the island which is opposite the deep break between the hills of Nova Scotia and New Brunswick, occupied by the Bay of Fundy, Chiegnecto Bay, and the low country extending thence to Northumberland Strait, an evidence that the boulder drift was connected with currents of water passing up this depression from the south or south-west. Similar local drift occurs in Nova Scotia (see Chap. V.), though there the predominant direction is from the northward.

Besides these boulders, however, there are others of a different character; such as gneiss, hornblende-schist, anorthosite and Labradorite rock, which must have been derived from the Laurentian

rocks of Labrador and Canada, distant 250 miles or more to the northward. These Laurentian rocks are chiefly found on the north side of the island, as if at the time of their arrival the island formed a shoal, at the north side of which the ice carrying the boulders grounded and melted away. With reference to these boulders, it is to be observed that a depression of four or five hundred feet would open a clear passage for the Arctic current entering the Straits of Belle Isle to the Bay of Fundy; and that heavy ice carried by this current would then ground on Prince Edward Island, or be carried across it to the southward. If the Laurentian boulders came in this way, their source is probably 400 miles distant in the Strait of Belle Isle. On the north shore of Prince Edward Island, except where occupied by sand dunes, the beach shows great numbers of pebbles and small boulders of Laurentian rocks. These are said by the inhabitants to be cast up by the sea or pushed up by the ice in spring. Whether they are now being drifted by ice direct from the Labrador coast, or are old drift being washed up from the bottom of the gulf, which north of the island is very shallow, does not appear. They are all much rounded by the waves, differing in this respect from the majority of the boulders found inland. I may add here that Laurentian boulders have been observed on the north shore of Nova Scotia.* Dr Honeyman records their appearance even on the Atlantic coast.

The older boulder clay of Prince Edward Island, with native boulders, must have been produced under circumstances of powerful ice action, in which comparatively little transport of material from a distance occurred. If we attribute this to a glacier, then as Prince Edward Island is merely a slightly raised portion of the bottom of the Gulf of St Lawrence, this can have been no other than a gigantic mass of ice filling the whole basin of the gulf, and without any slope to give it movement except toward the centre of this great though shallow depression. On the other hand, if we attribute the boulder clay to floating ice, it must have been produced at a time when numerous heavy bergs were disengaged from what of Labrador was above water, and when this was too thoroughly enveloped in snow and ice to afford many travelled stones. Further, that this boulder-clay is a submarine and not a subaerial deposit, seems to be rendered probable by the circumstance, that many of the boulders of the native sandstone are so soft that they crumble immediately when exposed to the weather and frost.

The travelled boulders lying on the surface of the boulder clay evidently belong to a later period, when the hills of Labrador and Nova Scotia were above water, though lower than at present, and were sufficiently bare to furnish large supplies of stones to coast ice carried

* Notes on Post-pliocene, 1872, p. 112.

by the tidal currents sweeping up the coast, or by the Arctic current from the north, and deposited on the surface of Prince Edward Island, then a shallow sand-bank. The sands with sea-shells probably belonged to this period, or perhaps to the later part of it, when the land was gradually rising. Prince Edward Island thus appears to have received boulders from both sides of the Gulf of St Lawrence during the later Post-pliocene period; but the greater number from the south side, perhaps because nearer to it. It thus furnishes a remarkable illustration of the transport of travelled stones at this period in different directions; and in the comparative absence of travelled stones in the lower boulder clay; it furnishes a similar illustration of the homogeneous and untravelled character of that deposit, in circumstances where the theory of floating ice serves to account for it at least as well as that of land ice, and, in my judgment, greatly better.

Subdivisions of the Pleistocene Deposits.—In Chapter V., and in my Memoirs on the Pleistocene of the St Lawrence Valley, I have proposed a threefold division of these beds into *Boulder clay*, *Leda clay*, and *Saxicava sand* and gravel, to which may be added the old peaty deposit observed under the boulder clay in Cape Breton. Mr Matthew has since recognised in New Brunswick certain beds only locally developed in the St Lawrence Valley, and which I have been hitherto disposed to regard as depending on the action of streams from the land or littoral agencies, but which he regards as marine deposits. They are gravels and sands underlying the boulder clay, and as yet destitute of fossils. He suggests for these the name "Syrtensian" beds, proposed by Packard for the fauna of the Great Bank deposits of the Newfoundland and New England coasts, but the application of which to the beds in question depends on a theory of their origin not yet certainly established. He also recognises, as I have done in the St Lawrence Valley, a lower and upper member of the Leda clay — the latter being equivalent in its fossils to the Uddevalla beds of Sweden. The complete series of Pleistocene beds in Acadia and Canada would thus stand as follows, in ascending order, though it is to be observed that the whole series is not to be found developed at any one place :—

(*a*.) Peaty terrestrial surface anterior to boulder clay.
(*b*.) Lower stratified gravels—(Syrtensian deposits of Matthew).
(*c*.) Boulder clay and unstratified sands with boulders. Fauna, when present, extremely Arctic.
(*d*.) Lower Leda clay, with a limited number of highly Arctic shells, such as are now found only in permanently ice-laden seas.
(*e*.) Upper Leda clay and sand, or Uddevalla beds, holding many

sub-Arctic or boreal shells similar to those of the Labrador coast at present.

(*f.*) Saxicava sand and gravel, either non-fossiliferous, or with a few littoral shells of boreal or Acadian types.

This table may be regarded as giving a complete statement of the series of deposits in the Post-pliocene, not only in the Acadian Provinces, but throughout North-eastern America.

Fossils of the Post-pliocene. — Since the publication of the second edition, the Rev. Mr Paisley has published in the "Canadian Naturalist" (1872) a list of shells obtained from a railway cutting on the Tattagouche River, near Bathurst, in New Brunswick. They were found in beds of Leda clay passing upwards into sand and gravel. At the Jacquet River in the same district, the bones of a small cetacean have been found, and have been described by Dr Gilpin and Dr Honeyman.* They are referred by Dr Gilpin to *Beluga Vermontana* of Thompson from the Pleistocene of Vermont. Similar bones have been found in the Leda clay of the St Lawrence Valley, and have been compared by the late Mr Billings with the skeleton of the recent *B. catodon*, L., of the St Lawrence, with which the so-called *B. Vermontana* is probably identical, as the specimens above referred to, and examined by Billings, certainly were.

In Prince Edward Island I have recorded the occurrence of Post-pliocene shells at Campbellton, and Mr Matthew has found *Tellina Grœnlandica* at Horton Bluff, in beds probably of the age of the Saxicava sand. Mr Matthew has also published † a valuable synopsis of the fossils found up to 1876 in the Post-pliocene of New Brunswick, in which the number of species of Mollusca is raised to more than thirty. He notes the important fact that the shells found on the coast of the Baie de Chaleur are of more northern type than those in the Bay of Fundy, which conform more nearly to the assemblage found in these deposits on the New England coasts, so that the existing geographical regions were already to some extent established on the coast of North America in the period of the Upper Leda clay.

5. THE TRIAS.

The principal addition to our knowledge of this formation is that contained in the Report by Dr Harrington and myself published in 1871.‡ In this we separated as Upper Carboniferous, or "Permo-

* Trans. Nova Scotia Institute, vol. iii. † Canadian Naturalist, vol. viii.

‡ Report on the Geological Structure and Mineral Resources of Prince Edward Island—Dawson & Harrington.

carboniferous," an underlying series of red and gray sandstones shales, holding Carboniferous plants, extending from near Cape W toward the north point, and a similar series found at Goverr Island and Gallas Point in Hillsborough Bay. These are undoubt extensions of the Carboniferous of Nova Scotia. All the rest of island is occupied with Triassic rocks; in one place, Hog Islan Richmond Bay, associated with trap. The general relations of tl rocks are seen in the sections.

The beds of the Triassic series, as seen in Prince Edward Isl consist chiefly of soft red sandstone, with some buff-coloured beds red and mottled clays. Associated with them are conglomerates hard calcareous and concretionary sandstones, passing into band arenaceous limestone, which is in some places a dolomite. following section in Orwell Bay and its vicinity shows the l resting on the Upper Carboniferous of Gallas Point, and ma taken as typical. It is in ascending order:—

]

1. Bright red sandstones with white bands . . . .
2. Red shales with white stains and red sandstones with cylindrical casts of fucoids . . . . . .
3. Red and purplish sandstones with gray bands and layers of ferruginous conglomerate with obscure remains of plants
4. Beach, probably representing soft beds . . . .
5. Red flaggy sandstone with conglomerate and concretions of red oxide of iron, containing remains of plants . .
6. Bright red sandstones and red shale with greenish stains .
7. Marsh, probably soft beds . . . .
8. Red shale and green bands capped with bright red sandstones . . . .

(Here the section is broken by Orwell Bay, which probably represents some thickness of soft beds.)

9. On the high cliffs near Belfast are very bright red sandstones and shaly beds, with gray blotches and cylindrical fucoids—about . . . .
10. Over the last are seen, in the country east of Belfast, soft red sandstones with beds of conglomerate with rounded quartz pebbles and arenaceous cement (thickness uncertain) .

As seen in this section, the whole thickness of these beds ca much exceed 500 feet. Of this the lowest 270 feet, being Nos.

5 inclusive, of the above section may be referred to the lower di' sion, or "Bunter," and the remainder to the upper division of t formation, or "Keuper." The dips are so low, and the beds much affected by oblique stratification, that those of the Trias cann be said to be unconformable to the underlying Carboniferous rock and for this reason, as well as on account of the similarity in miner character between the two groups, some uncertainty may rest (the position of the line of separation. That above stated depen(on fossils, or a somewhat abrupt change of mineral character, an on a slight change in the direction of the dip. These beds sprea over the greater part of the island, presenting a nearly horizont attitude, or lying in very flat synclinals and anticlinals. They ar well seen in the coast cliffs in many places, and several of thes coast sections are given in the Report above referred to.

The general sections (Figs. 2, 3) show the arrangement of thi formation and its relations to those of Nova Scotia.

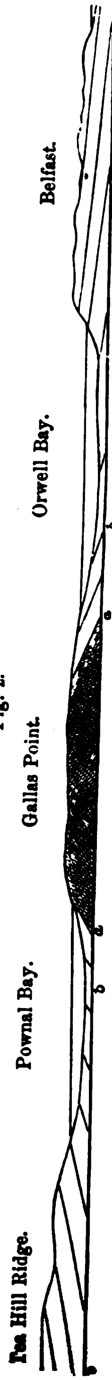
Fossils are rare in the Triassic beds. Of plants, one of the most interesting is a species of coniferous tree distinct from that occurring in the Carboniferous beds beneath, and allied to *Dadoxylon Keuperianum* of the European Trias. I have described it under the name *D. Edvardianum*. Another is apparently a small cycadean stem, which I have described as *Cycadeoidea* (*Mantellia*) *Abequidensis*, from the old Micmac name of the Island.* Beside these there are Knorria-like stems, a coarsely marked *Sternbergia*, and impressions resembling fucoids. The only animal fossil yet known is *Bathygnathus borealis*, Leidy, described in Chapter VIII. The added knowledge of such fossils since that chapter was written, now enables us to refer this animal to the group of carnivorous dinosaurs, the highest known reptiles, and to regard it as a terrestrial animal, probably provided with large hind limbs for leaping, and to enable it to assume an erect position at will. That remains of such creatures should be exceedingly few is not wonderful, when we consider that at the time when they lived Prince Edward Island must have been a submarine bank, on which the carcases of animals living on the neighbouring lands must have been very rarely deposited, even if we suppose these lands extensive and well peopled with reptilian forms.

6. THE PERMO-CARBONIFEROUS.

Chapter IX., headed "The Permian Blank," is devoted to th inquiry as to whether any part of the uppermost layers of the Ca boniferous may, in part at least, represent this system of formations

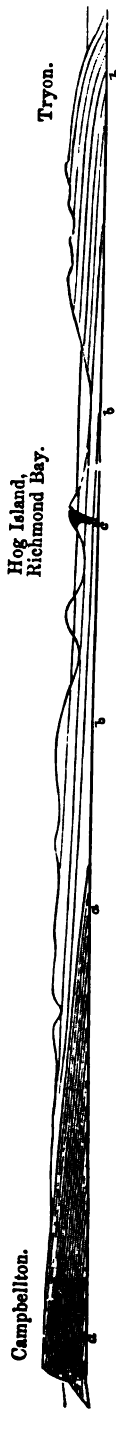
* Report, p. 45.

Fig. 2.



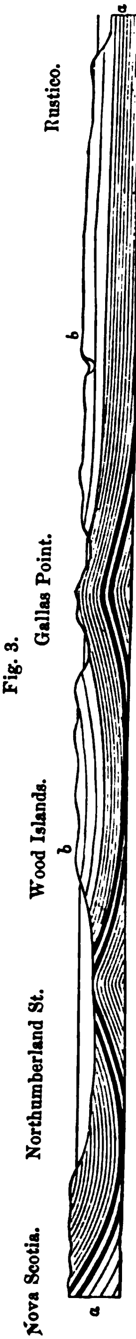
General Section on Coast of Prince Edward Island, from Tea Hill to Belfast.

Fig. 2 a.



General Section across Prince Edward Island, from Campbellton to Cape Tryon

Fig. 3.



Ideal Section, showing the probable relations of the Trias of Prince Edward Island to the Carboniferous.

developed elsewhere. The information obtained in the survey of Prince Edward Island in 1871, and followed up by re-examination of the upper members of the Carboniferous in Nova Scotia, has enabled me to give in a paper, presented to the Geological Society of London in 1874, a more definite reply to this question, and to affirm that we have at least a Permo-carboniferous formation closing the Carboniferous period, and whose fossils indicate that it represents beds of transition between the Carboniferous and Permian. This passing of the Coal formation upwards into the Permian is not without parallel elsewhere. It is observed both in England and Western America, and has led many to regard the Permian rather as an upward extension of the Carboniferous than as a distinct group. Where best developed, however, as in England and Germany, the Permian or Dyas is certainly to be regarded as a distinct formation; and even where its beds are absent, the lapse of long time is indicated by the disturbances of the Carboniferous and the entire change of life on entering the Trias. For the details of the facts bearing on the Permo-carboniferous of Prince Edward Island and Eastern Nova Scotia I must refer to the paper above mentioned,* but may give here some of the more salient points.

The Upper Coal formation was first distinguished as a separate member of the Carboniferous system in Eastern Nova Scotia by the writer, in a paper published in the first volume of the Journal of the Geological Society, in 1845 — and was defined to be an upper or overlying series superimposed on the productive Coal-measures, and distinguished by the absence of thick coal-seams, by the prevalence of red and gray sandstones and red shales, and by a peculiar group of vegetable fossils.

Subsequently, in my paper on the South Joggins† and in Acadian Geology, this formation was identified with the upper series of the Joggins section, Divisions 1 and 2 of Sir William Logan's sectional list, and with the Upper Barren Measures of the English Coal-fields, and the third or upper zone of Geinitz in the Coal formation of Saxony.‡

Still more recently, in the "Report on the Geology of Prince Edward Island," 1871, I have referred to the upper part of the same formation, the lower series of sandstones in Prince Edward Island not previously separated from the overlying Trias.§

In Prince Edward Island, however, where the highest beds of this

* Journal Geological Society, August 1874.

† Journ. Geol. Soc., vol. x.

‡ Ac. Geol., p. 149.

§ Report on the Geological Structure of Prince Edward Island.

series occur, they become nearly horizontal, and are overlain apparently in a conformable manner by the red sandstones of the Trias, which differ very little from them in mineral character. It thus happens that, but for the occurrence of some of the characteristic Carboniferous plants in the lower series, and of a few equally characteristic Triassic forms in the upper, it would be difficult to affirm that we have to deal with two formations so different in age.

In connexion with this, the presumed absence of the Permian, not only here but throughout Eastern America, raises the question which I have already suggested in Acadian Geology, whether the conditions of the Upper Coal formation may not have continued longer here than in Europe, so that rocks in the former region constituting an upward extension of the Carboniferous may synchronize with part at least of the Permian. On the one hand, there seems to be no stratigraphical break to separate these rocks from the Middle Coal formation of Nova Scotia; and their fossils are in the main identical. On the other hand, where the beds are so slightly inclined that the Trias seems conformable to the Carboniferous, no very marked break is to be expected; and some of the fossils, as the conifers of the genus *Walchia* and *Calamites gigas*, have a decided Permian tendency.

On the whole, in the Report above referred to, I declined to separate the red beds of the lower series in Prince Edward Island from the Newer Coal formation. Prof. Geinitz, however, in noticing my Report,* and also in a private letter, expresses the opinion that the fossils have, as an assemblage, so much of a Permian (or Dyadic) aspect that they may fairly be referred to that formation, more particularly to its lower part, the Lower Rothliegende. Attaching, as every one must, great weight to the judgment of Prof. Geinitz on such a point, I determined to re-examine the more instructive sections of the Newer Coal formation on the eastern coast of Nova Scotia, with the view of ascertaining whether any stratigraphical or palæontological line can be found to divide the Upper Coal formation series of my former papers into two members, or to separate it from the Middle Coal formation. The results of this re-examination and their bearing on general geological questions may be stated as follows:—

The Carboniferous district of Pictou county, extending for about 45 miles along the shores of Northumberland Strait, exposes in that distance, in coast and river sections, the whole thickness of the Carboniferous system, arranged in three synclinal forms.

The *First* or eastern synclinal, extending from the older metamor-

* Neues Jahrbuch, 1872.

phic rocks on the eastward and southward to a line running nearly east and west through the town of New Glasgow, consists entirely of the Lower Carboniferous, Millstone-grit, and Middle Coal formation, and contains all the known workable Coal-measures of the county. Its northern boundary, the New Glasgow anticlinal, brings up a bed not recognised in the other Nova Scotia Coal-fields—the New Glasgow Conglomerate, an immense mass, believed in some parts to be 1600 feet in thickness,* and containing boulders 3 feet in diameter, with pebbles of all sizes, many of its largest stones being composed of the hard brown or purplish sandstones of the Lower Carboniferous. Its stratigraphical position is that of the upper part of the Millstone-grit or lower part of the Middle Coal formation; and it is evidently an exceptional bed, representing an immense bar or beach of gravel and stones, stretching from the eastern end of the metamorphic chain of the Cobequid Mountains across the Pictou Coal-field, and protecting those deep swamps in which the Pictou main coal, 36 feet thick, and its black shale roof, more than 1000 feet thick, were deposited. The theory of this remarkable deposit, one of the most singular connected with any coal-field, is fully discussed in the second edition of my "Acadian Geology." I may merely remark that, facing, as this bed does, the open sea stretching to the northward in the Coal formation period, it is not unreasonable to suppose that it indicates the action of heavy ice grounding on the shores behind which grew the *Sigillaria* forests of the Coal-swamps. The arrangement of the beds in the first synclinal, which is that of the great Pictou Coal-beds, has recently been worked out in much detail by Sir W. E. Logan and the late Mr E. Hartley.

The *Second* or middle synclinal extends from New Glasgow to Carribou Harbour, and centres in the deep indentation of Pictou Harbour. On its southern side it contains, north of New Glasgow, the depauperated equivalent of the Middle Coal formation; and the remainder of it is occupied by the Newer Coal formation, whose newest beds, however, are not represented in this trough. The low anticlinal which separates it from the third trough brings up nothing older than the lower part of the Newer Coal formation.

The *Third* synclinal extends from Carribou Harbour to Cape John, and, stretching westward through the Cumberland Coal-field, shows in its centre the newest beds of the Upper Coal formation, here more especially referred to.

It is to be observed that in these synclinals the north-west sides

* This is Sir W. Logan's estimate, and is warranted by the breadth which the bed occupies in the section; but there are indications that it thins rapidly toward the dip.

have steeper dips than the south-east sides, and consequently occupy a less breadth on the map. The south-east sides also show the best and most continuous sections; and for this reason I shall select the section from New Glasgow to Pictou Harbour, and that from Carribou Harbour towards Cape John, as typical of the lower and upper parts of the Upper Coal formation.

Section on the East River of Pictou.

1. In the river section, below New Glasgow bridge, the conglomerate is succeeded in ascending order by a gray concretionary limestone 20 feet thick, associated with sandstone and shale, and containing in some layers great numbers of the *Spirorbis*, which I have described as *S. arietinus*,* and whose habits of life were probably not dissimilar to those of *S. carbonarius*, so abundant in the Coal-measures. This limestone does not appear in the immediate river section, but on the flank of the conglomerate east of New Glasgow.

2. Above this is a series of black shales and underclays with gray sandstones and some reddish and purple shales, and thin seams of bituminous shale and coal. These beds contain *Stigmariæ*, *Lepidodendra*, Entomostracans, and fish-remains; the fossils and the mineral character of the beds alike corresponding with those seen in the upper part of the Coal-measures south of the conglomerate. The thickness of these beds is about 400 feet.

3. This series is succeeded by a thick gray sandstone holding *Calamites*, *Calamodendron*, trunks with aerial roots (*Psaronius*), etc., 30 to 50 feet thick. This appears at the mouth of Smelt Brook, and in several quarries to the eastward of that place.

4. Above this is a second series of dark shales and underclays, and bituminous shales associated with gray sandstones, and containing fossils similar to those of the series below. It especially abounds in fish-scales and *Cythere;* and several of the fishes are specifically identical with those of the upper part of the Middle Coal-measures, as seen in the southern trough south of New Glasgow. These beds are about 200 feet thick. Mr H. Poole has described them in the "Canadian Naturalist" for August 1860.

5. The beds up to this point may be considered the equivalents of the Middle Coal-measures, or of the upper part of them, and are now succeeded in ascending order by thick gray and reddish sandstones, and reddish and gray shales, including, however, thin coaly

* Report of Geol. Survey of Canada. This limestone may be compared with the "*Spirorbis* limestone" of the Shrewsbury, Lancashire, and Warwickshire Coal-fields in England. Hull, "Coal-fields of Great Britain." See also Note 3, p. 102.

beds and underclays, and clays with nodular limestone. These may be regarded as belonging to the Upper Coal formation; and their aggregate thickness as far as Pictou Harbour may be 2000 feet. They contain *Calamites*, trunks of *Dadoxylon materiarium*, *Lepidodendron*, *Pecopteris arborescens?* and *Neuropteris*.

The dip of the conglomerate is high; and that this is not altogether due to false stratification is shown by the fact, that to the eastward of New Glasgow the limestone and the Coal-measure beds rest on the conglomerate at an angle of 45°; but this rapidly diminishes to 20°, and in the greater part of the section it is only from 8° to 6°.

The line of demarcation between the Middle and Upper Coal formations is not marked here by any great physical break, but merely by the cessation of the characteristic beds of the Middle Coal formation and the change to sandstones associated with red shales.

At first sight it might appear that as the beds north of the conglomerate dip uniformly to the north, and mostly at slight angles, and those south of its outcrop are much more disturbed, there might be evidence of unconformability. This, however, is due to a line of fault extending along the outcrop of the conglomerate, and to the greater relative disturbance of the beds of the southern synclinal.

Section West of Carribou Harbour.

This section exposes the south side of the third or northern synclinal, and may be supposed to begin not far above the base of the Upper Coal formation. It extends in ascending order obliquely across the synclinal for about ten miles, along a coast in which the beds are on the whole well exposed, with uniform dips of about N. 30° E. magnetic, or nearly true north, and at an angle of about 10°; and no break or evidence of unconformability exists throughout the series, which amounts here in thickness to about 2500 feet.

The lowest beds seen in this section at the mouth of Carribou River are red and gray shales, and gray, red, and brown sandstones, including a small bed of coal 5 inches thick, with *Stigmaria* rootlets in the underclay; and at Carribou Island, nearly in the line of strike, there is a somewhat thicker bed of coal. The overlying series may be described as consisting of indefinite alternations of shales, mostly deep red, with sandstones, gray, red, and brown, the latter sometimes coarse and pebbly, and occasionally in thick massive beds. Several of the beds of shale contain concretions of limestone, in one case forming a nearly continuous bed, and with no fossils except a few casts of a *Cythere*. In one of the lower beds of sandstone seen on Carribou

River there are concretions of gray copper, and fossil trunks of trees penetrated by this mineral; and some of the fossil trees found in the sandstones on the coast are partly mineralized with sulphate of baryta.

The only material difference in mineral character is that red beds become more prevalent toward the upper part of the section, where the general character of the series is precisely that of the supposed Upper Coal formation rocks at Miminigash, Governor's Island, and Gallas Point in Prince Edward Island, and on the coast of New Brunswick at Cape Jourimain.*

The following statements, reduced from my sectional lists, will serve to illustrate these points of mineral character.

In the whole section the sandstones, including the argillaceous sandstones, are to the shales in the proportion of about two to one in vertical thickness, and the gray and buff sandstones are about equal to those which are brown and red, while the red and mottled shales greatly preponderate over those which are gray.

In the lower half of the section, extending to the mouth of Toney River, the gray sandstone, red sandstone, and shales (mostly red) are in the proportions of $4\frac{1}{2}$, 3, $6\frac{1}{2}$. In the upper half of the section they are in the proportions of $4\frac{1}{2}$, $5\frac{1}{2}$, 3; so that red sandstones become decidedly more prevalent in the upper part, where there is also a greater proportion of coarse pebbly sandstones and of light-red shale with greenish stains.

If we compare this with the upper part of the Joggins section as given in Sir William Logan's lists, we find a thickness of 2267 feet; and if we regard the Ragged Reef Sandstones as equivalent to the heavy sandstones at the base of the Pictou section, it is possible that the upper part of the latter is not represented at the Joggins. Taking the proportions of sandstones and shales at the latter place, we find them to be gray sandstone 12, red and brown sandstone 1, shale 10; so that here the proportions of sandstones to shales are not very dissimilar to those in the lower part of the Pictou series, but the gray sandstones are greatly more prevalent. Like those in the upper part at Pictou, some of the upper beds at the Joggins are coarse and pebbly, a character not observed in either Coal-field, in the sandstones of the Middle Coal formation.

If, on the other hand, we turn to Prince Edward Island, the geological relations, and especially the fact that the outcrops on Prince Edward Island correspond with the extension of two of the New Brunswick Carboniferous anticlinals, would lead us to believe that

* Report on Prince Edward Island.

the Upper Coal formation beds seen at Gallas Point, and amounting to about 800 feet in vertical thickness, must belong to the upper part of the Pictou series, or may even reach some way above its summit. Accordingly, we find the proportions of the several rocks to be, gray sandstone 2, red and brown sandstone 4, shales 2, or a still greater proportion of red sandstone as compared with Pictou. All this accords with the idea of a gradual increase of red beds in approaching the summit of the formation, so that the Upper Coal formation passes in its upper part into beds having more the aspect of some parts of the Lower Dyas or Permian. No true dolomite is present in these beds; but Dr Harrington's analyses show that some of the thin beds of concretionary limestone are highly magnesian, and the sandstones contain concretions of sulphate of copper, while the fossil trees which abound in them are often mineralized with sulphides of copper and iron, and sulphate of baryta.

In the paper referred to, lists are given of the characteristic fossil plants in the upper beds, and it is shown that the species found, though mostly common to these beds and the Middle Coal formation, constitute a peculiar group, having strong points of resemblance with the flora of the Lower Permian in Europe.

In Prince Edward Island the Upper Carboniferous and the Trias are apparently conformable, and may almost be said to pass into each other, though in Nova Scotia the Trias rests unconformably on the Carboniferous. I believe, however, that this apparent conformity in Prince Edward Island, and the resemblance of the two series in mineral characters, arises from the almost horizontal position of the Carboniferous beds, and from the circumstance that the Trias has been in part formed from their waste. The Triassic fossils, though few, are of species quite distinct from those of the Carboniferous. Further details as to the relations of these formations in Prince Edward Island will be found in my Report on that island.

To sum up, it may be said that the beds which overlie the Coal-field of Pictou and extend into Prince Edward Island, and which constitute the upper part of the Upper Coal formation, have such strong points of resemblance to the lower part of the European Permian, both in their mineral character and organic remains, that they may fairly be named Permo-carboniferous, a name already applied to certain marine limestones in the West, in which the Carboniferous graduates upward into the Permian. They may also be held to some extent to bridge over the gap which in Eastern America generally separates the Carboniferous from the Trias.

I may add that in Nova Scotia the Lower Carboniferous beds are

usually more hardened and altered than those of the Middle Coal formation, and the latter more than those of the Upper Coal formation. Moreover, there are instances in Nova Scotia of local unconformability of the Lower Carboniferous beds; and the New Glasgow conglomerate affords evidence of extensive denudation of the Lower Carboniferous before the deposition of the productive Coal-measures. These facts indicate the long duration of the Carboniferous period and the extent of the physical changes which it included; and it is evident that, had unconformability or extensive local denudation occurred somewhat higher in the system, it might have been regarded as forming the base of an overlying Permian series.

Detailed descriptions and sections of the Permo-carboniferous beds as they occur at Gallas Point, Governor's Island, and Campbellton, in Prince Edward Island, are given in the Report above referred to.

7. THE CARBONIFEROUS.

With reference to the structure and stratigraphy of the Carboniferous, a large amount of work has been done by the officers of the Geological Survey, principally in the Cape Breton, Pictou, and Cumberland areas, and more especially in the productive Coal-measures. Much has also been done by private explorations, and the results are so voluminous that I can scarcely do more than refer to the Reports in which the principal of them are contained.

Discoveries in different Coal-Fields.

In the Report of the Geological Survey for 1872-3, Messrs Bailey and Matthew have given details of the Coal-field of New Brunswick, derived both from surveys and from borings made by Mr Ells. The most remarkable general result is the small thickness of this widely-extended Coal formation area. The estimate given is as follows, in ascending order:—

Gray sandstones and shales, equivalent of Mill-stone-grit	200 feet.
Coal-measures containing no known bed thicker than 26 inches	200 "
Upper Coal formation	200 "
	600 "

Perhaps there should be added to this a small additional thickness for the Permo-carboniferous of the shore of Northumberland Strait. But in any case it presents a great contrast to the vast thickness of

the Carboniferous system in the Pictou or Cumberland areas, amounting to many thousands of feet, and shows how very unequal subsidence and deposition must have been even in neighbouring areas not separated by any physical barrier. The facts thus ascertained do not increase the probability of the discovery of valuable coals in this great area. Some of the widely-extended thin beds may perhaps admit, at some time, of being worked on a large scale, and possibly large beds may exist in the central part of the area remote from the older rocks, or on the north-eastern coast. The coast between Bathurst and Miramichi River, and that between the latter and Buctouche, afford perhaps some of the most promising localities.

The Cumberland Coal-field has attracted much attention, and more especially that part of it in the Springhill district which is traversed by the Intercolonial Railway, affording so great facilities for the transmission of its produce. Mr Barlow reports* that in the Springhill areas eight or nine seams of coal have been discovered, the principal one being 11 feet in thickness, and affording coal of very good quality. There is an overlying seam 13 feet thick, but with two clay partings. Mr Hartley gives as the analysis of the Springhill coal:—

Volatile matter	35·39
Fixed carbon	60·46
Ash	4·15
	100·00

So that this appears to be an excellent coal, altogether superior to that of which I have given an analysis (Ac. Geol., p. 221), and which was an outcrop sample, the only one that I could at that time obtain.

The Reports of Sir W. E. Logan and Mr Hartley (Geol. Survey Reports, 1869) have added greatly to our knowledge of the structure of the Pictou Coal-field, and more especially of the faults traversing it, and the distribution of the measures on the east side of the East River, and the actual productive limits of the Coal-field. A detailed map accompanies the Report, and Mr Hartley has given tables of analyses and practical trials of the coals. On the east side of the East River, the trough-shaped arrangement already referred to appears to continue as far as the left bank of Sutherland's River. A subordinate anticlinal appears, however, to occur in the middle of the trough, or rather nearer the East River, and there are a number of faults, both parallel and transverse to the axis of the trough. In the

* Report Geol. Survey, 1866–69.

western end of this part of the trough, that nearest the East River, no important extension of the great seams of the Albion mines appears yet to have been distinctly recognised, though these seams, or their equivalents, must exist both on the south side towards M'Lellan's brook, and on the north side near New Glasgow (see the map, Ac. Geol., p. 320). The beds of coal which have been worked near the east side of the East River, the Foster and Lawson seams, are believed to overlie the great main seam by a thickness of about 1500 feet. In the eastern half of the trough these upper beds are apparently represented by the Marsh Brook seam, the George M'Kay seam, and associated beds; and the correspondence of the beds and their containing measures, as well as in the quality and structure of the coal, seem to establish this equivalency. But here, at a distance of 480 yards to the rise, occurs the M'Bean seam, now worked in the Vale Colliery, and associated with other seams, making in all so great an aggregate of coal, that they may not unreasonably be regarded as the equivalents of the main seam. In this case, however, the thickness of the overlying measures must have diminished or been concealed by faults, and on that account it is still possible that the real equivalents of the main seam may occur lower down. The M'Lean beds, not yet worked, lying to the westward of the explored part of the M'Bean seams, may in the one case be the continuation of the M'Bean series, or in the other may be much lower. There can be little doubt that these M'Lean beds represent the main seam. The great inequality of the original deposits in this Coal-field, and the disturbances to which they have been subjected, with the absence of good natural sections, oppose great obstacles as yet to the decisive settlement of these questions—the answers to which are, however, being gradually worked out by mining explorations.

In 1868, immediately after the publication of my second edition, I had an opportunity to examine some parts of the coast of Cape Breton, and more carefully to correlate the Coal-beds of that region, as well as to make some important observations on fossil plants. These observations have not been published in full, but in the same year I sent a note relating to them to the Nova Scotia Institute, which was printed in their Transactions, and gives my views on these subjects as formed at that time.

The following section of the Coal formation, as exposed on the south side of Sydney Harbour, on the property of the Victoria Mining Company, is condensed from observations made with the aid of Mr Ross, of the Victoria Mine, and Mr Mosely of Sydney. The order is descending.

		Ft.	In.
1.	"Carr" Seam	4	
	Sandstone, Shales, etc., about .	429	
2.	"Paint" Seam	13	4
	Sandstones, Shales, etc., about .	216	
3.	"Crandall" Seam . . .	4	4
	Sandstones, Shales, etc., about .	400	
4.	"Ross" Seam	6	7
	Sandstones, Shales, etc., about .	325	
5.	"William Fraser" Seam . .	2	
	Sandstones, Shales, etc., about .	112	
6.	"Number Three" Seam . .	4	
	Sandstones, Shales, etc., about .	138	
7.	"H. M'Gillivray" Seam . .	5	
	Sandstones, Shales, etc. . .	122	
8.	"D. M'Gillivray" Seam . .	2	
	Sandstones, Shales, etc., about .	1000	
9.	"Fraser" Seam	6	
	Sandstones (Millstone-grit series).		

This series of Coal-beds I believe to represent the whole of the workable beds known at North Sydney as well as those of Glace Bay and Cow Bay. The high angle of dip brings their outcrops nearer to one another than is usual in this district, and a good coast cliff and beach section enables them to be well studied. This section is the best guide I have seen to the vexed question as to the equivalents of the several Coal-beds in the different mining areas of Cape Breton, but its application is by no means easy. On the south side of Sydney harbour the Coal-beds above-mentioned dip about N. 5° E. at angles of 30° to 45°. On the opposite side of the harbour the corresponding beds dip to the north-east at an angle of 10 degrees or less. Consequently the beds, crowded together on the south side, spread out like a fan on the north side. In addition to this, when we measure the thickness of the beds intervening between the several seams of coal, it is evident that they must vary greatly both in character and thickness within very short distances. Making due allowance for these differences, it would seem that the Paint seam of the above list must be the Lloyd's Cove seam of the North Sydney series. In this case the main seam at North Sydney is equivalent to the Ross seam. The equivalency of these beds with those of Glace Bay and Cow Bay is more uncertain. I was inclined to correlate the Paint seam with that known as the Phelan at Glace Bay, and to suppose that the lower seams were still to be found there; but different views

have been stated by Mr Robb, which would tend to diminish somewhat the probable importance of the lower beds of coal underlying those worked at Glace Bay and Cow Bay. These, however, include the equivalents of the Gardiner seam and the M'Gillivray seams. To these points I may add the statement that in my sketch map, page 413, the strike of the beds at the east side of Sydney Harbour should turn a little more to the south, and that the outcrops should be closer to each other; and that, by an error in the engraving, the town of Sydney is removed from its true position on the southern arm of the harbour to the south-west bar. I am indebted to Mr Mosely of Sydney for information bearing on some of these points.

In the Reports of the Geological Survey for 1872–3, 1873–4, and 1874–5, Mr Robb has gone with great elaborateness into these questions, and correlates the Sydney main seam not only with the Ross or Victoria, but with the David's Head seam of Bridgport, the Harbour seam of Glace Bay, and the Block-House seam of Cow Bay. Mr R. Brown has stated a similar view of the equivalency of these beds in his work on the Coal-fields of Cape Breton.*

Leaving these local details, I may now refer to some curious fossil plants met with in the Coal formation of Cape Breton, and deserving of record as additions to our knowledge of its flora. Among the rarest of fossil plants in the Coal rocks of Nova Scotia have hitherto been the trunks of tree-ferns. The scattered fronds are sufficiently abundant, but trunks of arborescent species are seldom found. Mr Poole's collections at Glace Bay enable me to add another fine species to the Coal flora of Nova Scotia. It is a large flattened stem, a foot or more in diameter, marked with many wrinkles over the whole surface, and with large distant oval leaf-scars 1½ inch in diameter and 3 inches in length, to which large fronds must have been attached. It is a near ally of *Caulopteris macrodiscus*, Sternberg, but has larger and more distant scars, more obtuse above. I would name it *Caulopteris glacensis*. It belongs to the genus *Ptychopteris* of Corda. Another remarkable trunk, which I found obscurely preserved in coarse sandstone at North Sydney, appears different from anything hitherto described. It seems to have had four vertical rows of scars, the form of which could not be made out; but I have little doubt that it belonged to an arborescent fern with a stem 4 inches in diameter and several feet at least in height. Near an abandoned coal-mine at Bridgeport I also found a fragment of one of those tree-ferns surrounded with aerial roots, to which the name *Psaronius* has been given, but not admitting of specific description.

* London, 1871.

As I have been able hitherto only to describe four species trunks of tree-ferns, these are considerable additions. Among oth interesting specimens in the collection of Mr Poole, I also saw tl curious sigillaroid tree *Syringodendron cyclostigma*, Brongniart, and species of *Sigillaria* new to Nova Scotia and allied to *S. rugosa* (Brongniart, though scarcely sufficiently perfect for description Another remarkable form collected by Mr Poole is a flattene striated stem about an inch in width, with two rows of punctiform marks at the sides, and giving off alternate slightly curved branches, at right angles, and in one plane. It may have been the stipe of a fern.

Another interesting fossil observed at North Sydney was an erect *Sigillaria*, with that peculiar bulb-like enlargement of the base figured by Sternberg on Plate xxxviii. of his great work, but which I had not before seen, the *Sigillariæ* found in Nova Scotia usually enlarging regularly towards the base in the manner of ordinary trees. This bulb-like appearance seemed to be a natural feature of the growth of the plant, which had the markings of *S. reniformis*. Through the kindness of my friend Mr Brown, of the Sydney colliery, the specimen was carefully taken down from the cliff, and forwarded to Montreal; and it now stands, a column five feet in height, in the museum of M'Gill University.

Since 1868, the Coal-field of Campbellton, an extension northward of the Sydney series, lying against the ancient Syenitic ridge of St Anne's Mountain, has been explored, and coal-workings commenced in it,* and the extension of workable Coal-measures has been traced on the west coast of Cape Breton, north of Mabou, in Broad Cove. These have been reported on by Professor Hind. The boundaries of the Millstone-grit and Carboniferous limestone in the vicinity of Sydney Harbour have also been carefully mapped by Mr Fletcher of the Dominion Geological Survey.

Lower Members of the Carboniferous.

Turning now to the lower members of the Carboniferous series; in connection with a Report on the Fossil Plants of the Lower Carboniferous and Millstone-grit Formations,† I have endeavoured to classify these, and to indicate their equivalency with formations abroad, a subject at present exciting some controversy among European geologists.

Where most fully developed in Nova Scotia and New Brunswick, these formations may be thus subdivided in ascending order :—

* Report Geol. Survey, 1873-4. † Geol. Surv. of Canada, 1873.

1st. *The Horton Series or Lower Carboniferous Coal-measures*, consisting of hard sandstones and shales often calcareous, associated with conglomerate and grit, and in some places with highly bituminous shales. They contain underclays and thin coaly seams, remains of plants, fishes, and entomostracans, and footprints of batrachians, but no strictly marine remains. This group was first established as a distinct subdivision of the Carboniferous in Nova Scotia, by Sir C. Lyell and the writer in 1844 and 1847. (See Note 2, p. 99.)

2d. *The Windsor Series or Lower Carboniferous Limestone and Gypsiferous Beds.*—This is a marine formation holding characteristic shells and corals of the Lower Carboniferous period, and containing in addition to the limestone thick beds of sandstone, marl, and clay, usually red, and of gypsum. First defined by Sir C. Lyell in 1843.

3d. *The Millstone-grit Series*, consisting of sandstones and shales, often red, and conglomerate, associated with dark-coloured beds holding fossil plants and *Naiadites*, and with a few underclays and thin seams of coal. The name Millstone-grit was first applied to these as a distinct group by Mr R. Brown in 1844. The group was distinctly indicated in Sir W. E. Logan's section of the South Joggins in 1843, and in my paper of the same year on the Lower Carboniferous rocks of Eastern Nova Scotia.

Above these are (4th) the *Middle Coal formation*, and (5th) the *Upper or Newer Coal formation* with the overlying *Permo-carboniferous Series.*

In some localities the lower member is absent, the marine limestones resting on the older rocks. In other localities the marine member is absent, or very slenderly developed, and the Lower Carboniferous Coal measures and Millstone-grit are united together. In this case, however, the lower series is usually represented by coarse conglomerates with few fossils.

The equivalency of these beds with formations abroad is a subject of some importance, more especially with respect to the Horton series or Lower Carboniferous Coal measures, as errors have been committed both in the way of confounding these with the Coal measures above and with the Devonian below; and in works of general geology very little attention is usually given to them as a distinct group. With regard to the marine limestones, their equivalency to the Lower Carboniferous limestones of other countries is undoubted. The Millstone-grit also admits of very little difference of opinion as to

its equivalents. In the following lists I have given the equivalents of the Horton series and Millstone-grit series as they appear to me to be settled by stratigraphy and fossils:—

1. *Equivalents of the Lower Carboniferous Coal-Measures or Horton Series.*

(1.) The Vespertine Group of Rogers in Pennsylvania.
(2.) The Kinderhook Group of Worthen in Illinois.
(3.) The Marshall Group of Winchell in Michigan.
(4.) The Waverley Sandstone (in part) of Ohio.
(5.) The Lower or False Coal-measures of Virginia.
(6.) The Calciferous Sandstones of M'Laren, or Tweedian Group of Tate in Scotland.*
(7.) The Carboniferous Slate and Coomhala Grits of Jukes in Ireland.
(8.) The Culm and Culm Graywacke of Germany.
(9.) The Graywacke or Lower Coal-measures of the Vosges, as described by Schimper.
(10.) The Older Coal Formation of the Ural, as described by Eichwald.
(11.) The so-called "Ursa Stage" of Heer includes this, but he has united it with Devonian beds, so that the name cannot be used except for the local development of these beds at Bear Island, Spitzbergen.

All of the above groups of rocks are characterized by the prevalence of *Lepidodendra* of the type of *L. corrugatum*, *L. Veltheimianum*, and *L. Glincanum*, and also of the type of *L. tetragonum* of Sternberg (Bergeria of some authors),† pines of the sub-genus *Pitus* of Witham, *Palæoxylon* of Brongniart, and peculiar ferns of the genera *Cyclopteris*, *Cardiopteris*, and *Sphenopteris*. In all the regions above referred to they form the natural base of the great Carboniferous system.

* Some attention has recently been given to these beds in England and Scotland by Geikie, Hull, Lebour, and others, and new names have been proposed, as that of "Valentian" by Geikie. The name "Tweedian" of my old friend Tate should, I think, stand. Many years ago, when I was engaged in the study of these rocks, he seemed to be the only English geologist who knew much about them. Of late years much confusion has been introduced into the geology of these beds by some European palæo-botanists. Stur has, however, worked up their fossils in Silesia, as Eichwald had done in Russia, and in both regions they correspond very closely with the flora which I have found in Nova Scotia, and have described in the Report above referred to. Meek has also recognised this flora in Western Virginia.

† This type of *Lepidodendron* has been recognised even in Australia, but seems there to be referred to the Devonian age.

2. *Equivalents of the Millstone-Grit Series.*

1. The Seral Conglomerate of Rogers in Pennsylvania, etc.
2. The Lower Coal Formation Conglomerate and Chester Groups of Illinois (Worthen).
3. The Lower Carboniferous Sandstone of Kentucky, Alabama, and Virginia.
4. The Millstone-grit and Yoredale Rocks of Northern England, and the Culmiferous of Devonshire.
5. The Moor rock and Lower Coal Measures of Scotland.
6. Flagstones and Lower Shales of the South of Ireland and Millstone-grit of the North of Ireland.
7. The Jungste Graywacke of the Hartz, Saxony, and Silesia.

The vegetable fossils of this group differ from those of the beds below the marine limestones, and contain forms resembling or identical with those of the Middle Coal formation, into which, indeed, both lithologically and as to fossils, the Millstone-grit passes by imperceptible gradations.

The distribution of these series in the Acadian Provinces may be stated thus:—

In Gaspé and the Bay de Chaleur and along the northern margin of the New Brunswick Carboniferous district, the Lower Carboniferous formation presents the characters of the Bonaventure formation of Sir William Logan, the marine limestones being absent or little developed, and the prevailing rocks being conglomerates and sandstones with few fossils. (Logan, Report of 1863; Robb, Report of 1869; Acadian Geology, p. 227.)

In Southern New Brunswick the Lower Carboniferous Coal-measures are remarkable for the great thickness of bituminous and bitumino-calcareous shales which they contain. These rocks hold the remarkable vein of Albertite worked in this district. They contain numerous remains of fishes, and also of the characteristic Lower Carboniferous plants. (Bailey and Matthew, Report of 1871; Acadian Geology, p. 231; see also Note 2.)

In Southern New Brunswick and North-western Nova Scotia, the Millstone-grit is also largely developed. At the South Joggins, where this formation and the Middle Coal formation probably attain their maximum thickness, the equivalent of the Millstone-grit occupies in Sir William Logan's section a vertical thickness of no less than 5972 feet, and consists of red and gray sandstones, red and chocolate shales and conglomerates, with some dark shales, underclays, bituminous limestones, and thin unproductive coals. It contains species of *Sigillaria*, *Lepidodendron*, *Calamites* *Dadoxylon*, and *Cordaites*.

(Logan, Geol. Survey of Canada, 1845; Acadian Geology, p. 176.)

On the south side of the Cumberland Coal-field, the Lower Carboniferous beds appear to return to the type of the Bonaventure formation, and to consist principally of conglomerate and sandstone not rich in fossil plants, and these principally of the Millstone-grit horizon.

Crossing the ancient metamorphic ridge of the Cobequids, we find on their southern flanks conglomerates representing the lowest Carboniferous rocks. Above these there is a slender development of the marine limestones and a great thickness of hard sandstones and shales, representing the Millstone-grit and perhaps the lower part of the Middle Coal formation. These rocks form a long belt extending from Cape Chiegnecto till it unites with the Pictou Coal-field on the eastward. Their general arrangement appears to be that of a narrow trough much broken by faults. They afford a good representation of the flora of the Millstone-grit. (Acadian Geology, p. 263 *et seq.*)

On the south side of Minas Basin and Cobequid Bay a very wide area is occupied by Lower Carboniferous rocks; and at the cliff of Horton Bluff, and other places in its vicinity, these beds, which, from their large development in this locality, may be named the Horton series, are very well exposed, and contain abundance of their characteristic fossils. For their detailed description I may refer to my paper of 1858, Journal of Geol. Society, vol. xv., p. 63. (See also Acadian Geology, p. 252.)

Similar rocks are seen and have been described by the author near Windsor, at Walton and Noel, and at Five Mile River on the Shubenacadie, in all these places rising up from under the Lower Carboniferous limestones. (Journal of Geol. Society, vol. iv. p. 59, vol. vii. p. 335; Acadian Geology.)

Further east, on the Salmon River, and on the West, Middle, and East Rivers of Pictou, there is a great development of rocks of the Millstone-grit series, consisting largely of chocolate sandstones and shales, often very hard, and with bands of gray and dark-coloured beds holding plants. In this region the marine limestones extend upward into the Millstone-grit, so that it is difficult to establish any distinct line of separation, and the Lower Carboniferous Coal measures seem to be absent. (Journal of Geol. Society, vol. i. p. 26, 1843; Logan and Hartley, Reports on Pictou Coal-field, 1869; Acadian Geology, p. 316 *et seq.*)

In the Pictou Coal-field there are certain hard sandstones holding obscure fossil plants, which come up from beneath the Millstone-grit on the Middle River, and which I have regarded as Devonian. It is,

however, barely possible that they may represent the Lower Carboniferous Coal measures, otherwise wanting in this district.

The great and exceptional conglomerate of the Pictou Coal-district, known as the New Glasgow Conglomerate, appears to be a shingle bed of the Upper Millstone-grit or Middle Coal formation epoch. It stretches with some interruptions from Merigomish to Roger's Hill and Mt. Dalhousie, near the eastern end of the Cobequid Ridge, or about twenty miles, and is undoubtedly connected with the different developments of the beds of the Coal formation on the south and north of this line; and it implies very great and violent denudation of the Lower Carboniferous sandstones during the Coal formation period, as the fragments contained in it are largely composed of these sandstones, and are often of great size. (Acadian Geology, p. 321, *et seq.*; Logan, Report on Pictou, 1869.)

At the extreme eastern end of the Pictou Coal-field, where it is in contact with the Upper Silurian at M'Cara's Brook, the Lowest Carboniferous beds are conglomerates with interstratified trap, above which is marine limestone overlaid by the Millstone-grit series. (Journal of Geol. Society, vol. i. p. 329; Acadian Geology, section opposite page 125.)

In the Carboniferous area of Antigonish County we again meet with the dark shales and sandstones of the Horton group, holding their characteristic plants, and underlying the marine limestones and gypsums. I noticed these beds as occurring at Right's River in 1843;* and Dr Honeyman, who subsequently traced them further to the eastward, has kindly placed in my hands a small but interesting collection of their fossil plants.

The long belt of Carboniferous rocks extending along the west branch of the St Mary's River, has the mineral character and fossils of the Millstone-grit series in those places where I have examined it, except near Guysboro, where there are Lower Carboniferous limestones, and in the Strait of Canso, near Cape Porcupine, where the basal conglomerates appear. (Acadian Geology, p. 350.)

In Cape Breton a well-characterized representation of the Lower Carboniferous Coal measures or Horton series is seen in the sandstones, gray and black shales, and conglomerates which underlie the limestone and gypsum of Plaister Cove, while the Millstone-grit seems to be represented by the thick sandstones underlying the Coal-field of Richmond County. (Journal of Geological Society, vol. v.; Acadian Geology, p. 390 *et seq.*)

In Northern Cape Breton, from the Cape Dauphin section, as

* Journal Geol. Society, vol. i. p. 329.

described by Mr R. Brown, it would appear that the Lower Carbon ferous Coal measures are slenderly represented or concealed b faulting. Mr Brown has, however, recognised the Millstone-grit a underlying the Sydney and Glace Bay Coal-fields, and attaining t a thickness of 1800 feet. It consists largely of gray sandstone and holds *Sigillariæ*, *Calamites*, and *Lepidodendra*. (Brown, Journa Geol. Society, vol. iii. p. 258; *Ibid.*, vol. vi. p. 116.)

From a collection of fossils made by Mr R Bell in Western Newfoundland, and presented to the Museum of the M'Gill University by Donald Ross, Esq., it appears that the Lower Carboniferous limestone of that island holds the same fossils with that of Nova Scotia, and that it is overlaid by a series of beds corresponding to the Millstone-grit. This formation, however, contains beds of coal of workable size, abounding in remains of *Lepidodendra*, so that it would seem that in Newfoundland, as in Scotland, the workable coals extend farther down in the series than is the case to the southward.

For the flora of these interesting formations which form the lower portion of the Carboniferous, I must refer to the Report already mentioned. I may remark here in general terms, that in the area of the Acadian Provinces, the close of the Devonian was accompanied by great physical changes which removed the Devonian flora. In the Lower Carboniferous period, a meagre flora, different from that of the Devonian, took possession of the land. This was again partially removed by the subsidence leading to the deposition of the Lower Carboniferous limestones, and the Millstone-grit lying on these, forms, as to its flora, the dawn of the great Middle Coal formation. While the local elevation, subsidences, and denudations within the Carboniferous period were sufficient to cause some limited cases of unconformability, these are not comparable with those between the Devonian and the Carboniferous; and the Devonian fauna and flora are as a whole quite distinct from those of the Carboniferous, though there are some species of plants common.

In Eastern America, as in Great Britain, the conditions of coal accumulation seem to have set in earlier to the northward. The Coal-beds of Newfoundland belong to the Millstone-grit series. Those of Pictou are exclusively in the Middle Coal series, and apparentl in its lower part. Those of the Joggins seem to be rather higher i the series than those of Pictou, and in the United States there a workable beds of coal in the Upper Coal measures which are barr in Nova Scotia. This connects itself with the fact illustrated in r Report on the Devonian Flora (1870), that this flora in North Amer seems to have extended itself from the north-east,—a view wh

Heer and Professor Asa Gray also entertain with respect to the Tertiary floras. Facts now accumulating from the observations of recent Arctic explorers, make it more and more evident that the peculiar Lower Carboniferous flora was very widely distributed in circumpolar lands at the beginning of the Carboniferous period.*

Mr E. Gilpin, in a paper in the Transactions of the Nova Scotia Institute (vol. iv.), has directed attention to the peculiar manganesian limestone lying at the base of the Carboniferous on the East River of Pictou, and very distinct in character from the great bed of light-coloured limestone (*Lithostrotion* Limestone of Acadian Geology), lying above, and the still higher gray limestones. In my tabular arrangement of the Lower Carboniferous limestones (Ac. Geol., p. 281), I have not separated this lower bed, as it has no distinctness with regard to fossils; but its wide distribution and metalliferous character would now induce me to follow Mr Gilpin's arrangement, and recognise it as a separate subdivision. It reappears in Pictou County in New Lairg, and is represented elsewhere by the black limestone of Plaister Cove, Cape Breton, the "Black Rock" at the mouth of the Shubenacadie and the manganiferous limestone of Walton and Teny Cape. It is not improbable that the manganese in these limestones may be derived from the decomposition of volcanic *debris* proceeding from the contemporaneous igneous vents which produced the Lower Carboniferous traps. Its origin may thus be similar to that to which the manganesian nodules found so abundantly in the deep-sea dredgings of the "Challenger" have been attributed.

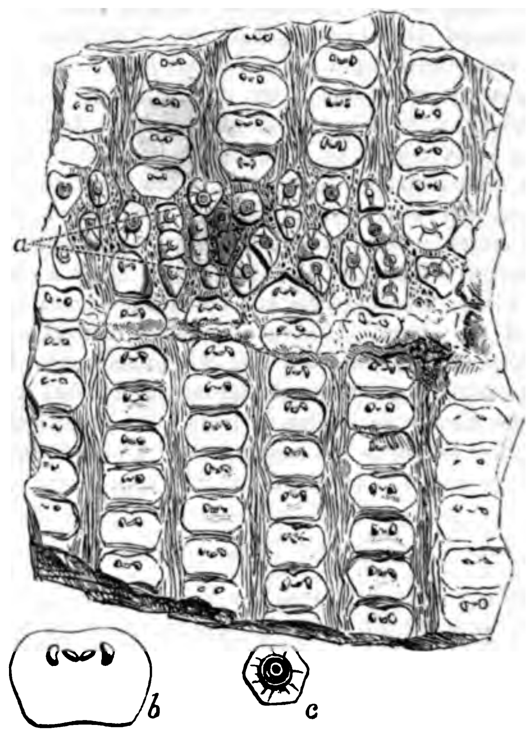
New Carboniferous Fossils.

In addition to the Report on the Lower Carboniferous and Millstone-grit plants already referred to, which gives a nearly complete view of this interesting flora as far as known up to 1873, I may refer to a paper on the Relations of *Sigillaria*, *Calamites*, and *Calamodendron*, in the Journal of the Geological Society for 1870; a paper on a remarkable *Sigillaria* discovered at the Joggins by Mr Hill (Proceedings of the same Society, 1877), Mr Scudder's descriptions of the five species of myriapods found by me in the Coal formation (Journal of Boston Society, 1873); Descriptions of Fossil Insects from Nova Scotia, by the same author (Canadian Naturalist, vol. viii.), and my own recent papers on a new crustacean (Geological Magazine, 1877), and on a recent discovery of Carboniferous

* See a summary of the latest of these facts in Geological Magazine, July 1877; also Heer, "Flora Fossilis Arctica," vol. iv.

Reptiles (Silliman's Journal, vol. xii., December 1876). I may add a paper on Impressions and Footprints of Animals and Imitative Markings on Carboniferous Rocks (Silliman's Journal, vol. v., January 1873), and the description of the remarkable footprints of *Sauropus unguifer* found in a quarry in Cumberland County.* It would be impossible to give here even the substance of these several

Fig. 4.—*Portion of Bark of Sigillaria Lorwayana*, Dn., *showing part of one of the Bands of Fruit-scars, which occur at intervals of a few inches on the trunk.*



Zones of Fruit-scars at (*a*, *a*, *a*). (*b*) Leaf-scar enlarged. (*c*) Fruit-scar enlarged.

contributions to palæontology, but I may notice a few points likely to be of interest to the general reader, or specially new in geological science.

In the Report on Fossil Plants above referred to, the species characteristic of the Lowest Carboniferous beds are defined and separated from those of the Devonian below and the Millstone-grit

* Geological Magazine, vol. ix.

above. Special attention is given to the protean varieties of *Lepidodendron corrugatum*, and to its *Stigmaria* roots, this being the characteristic Lower Carboniferous *Lepidodendron* in America, and our representative of the widely distributed *L. Veltheimianum* and its allies in Europe,* and also to the conifers of the Lower Carboniferous and Millstone-grit. A list is also given, for comparison, of the plants of the Middle and Upper Coal formation, and some inte-

Fig. 5.— *Wing of Blattina Bretonensis.* —Scudder.

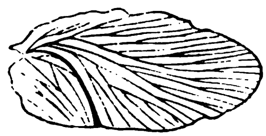
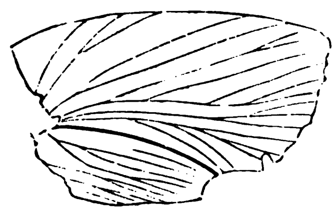


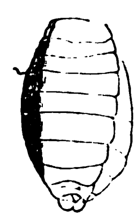
Fig. 6.— *Wing of Blattina Heeri.* —Scudder.



resting new species from the former are described—more especially *Sigillaria Lorwayana*, a species showing very beautifully the transverse bands of fruit-scars so characteristic of some species of *Sigillaria* (Fig. 4). In the paper on *Sigillaria*, it was my aim to define the true place and structure of that genus, and also to separate *Calamites* from *Calamodendron*. In connection with this I may mention that the *Cordaites*, whose leaves are so abundant in both the Devonian

Fig. 7.— *Wing of Blattina Sepulta.* —Scudder.

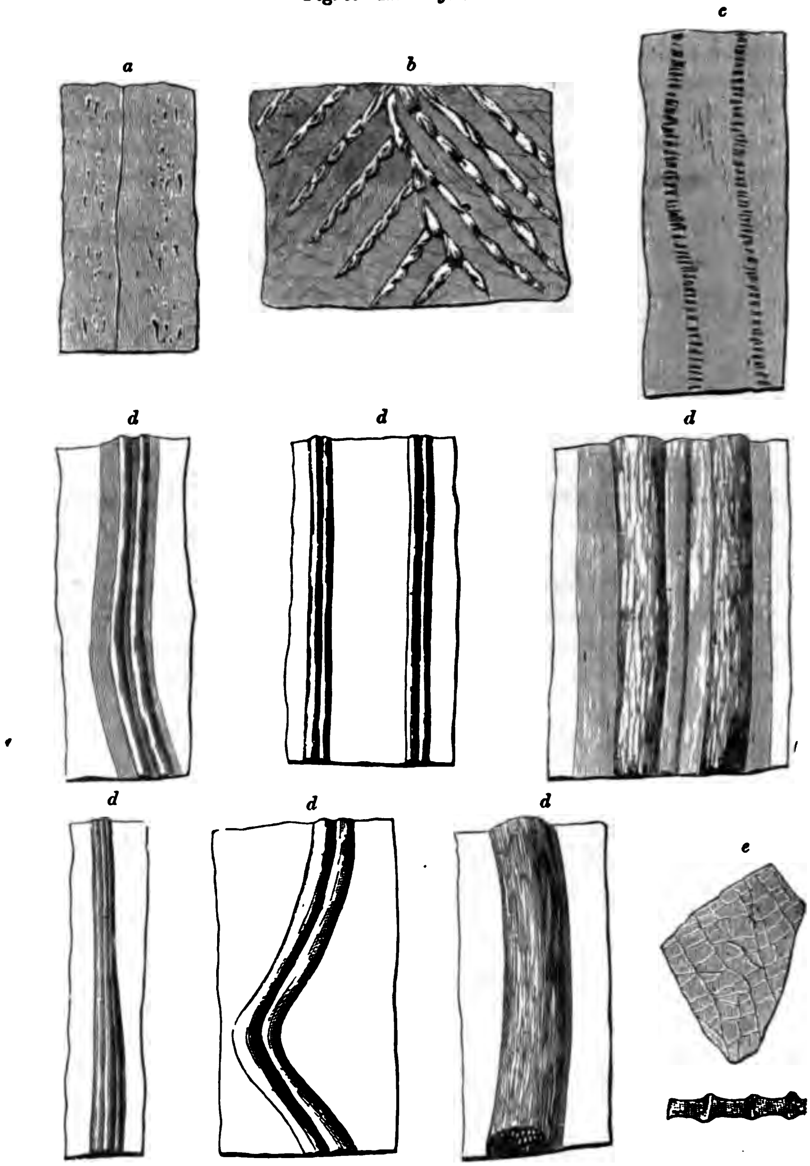
Fig. 8.—*Libellula Carbonaria.* —Scudder.



and Carboniferous, and in the latter constitute the substance of some thin layers of coal, have recently been shown by Grand 'Eury to

* I see that in recent descriptions of the Lower Carboniferous plants of Greenland, *L. Veltheimianum* is recognised; but this is probably *L. corrugatum*, which for want of sufficient specimens most European botanists have not yet learned to discriminate, nor have the Greenland specimens been yet compared with their American analogues. Until this shall be done, we must remain in some uncertainty respecting them, notwithstanding the good illustrations in European works.

Fig. 9.—*Markings on Rocks.*



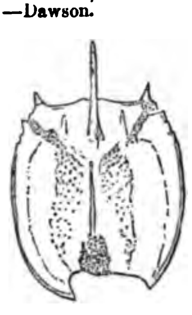
(*a*) *Protichnites Carbonarius* (nat. size), Carboniferous, Nova Scotia.
(*b*) *P. Acadicus*, " " "
(*c*) *Diplichnites ænigma* (reduced), " "
(*d*) *Rabdichnites*, different forms (nat. size), " "
(*e*) Carbonized plant with reticulated cracks filled with mineral matter, simulating a reticulate veined leaf (nat. size); *a*, enlarged section of part of the same. Carboniferous, Nova Scotia.

have belonged to trunks of advanced structure allied to that of conifers, and to have been gymnospermous plants. This gives them a higher position in the vegetable kingdom than that assigned to them in Acadian Geology, unless, indeed, there may be two groups included in this genus, the one lycopodiaceous, the other gymnospermous.

Among the new insects described by Mr Scudder (Figs. 6 to 8), that which he has named *Libellula Carbonaria*, and which was found by Mr A. J. Hill at the Cossit's Pit, near Sydney, C.B., is of especial interest as being the first known example of a Carboniferous dragon-fly (Fig. 8). This place, Cossit's Pit, is of especial interest, because it has afforded to Mr Hill a rich and varied flora, containing forms not yet described, and some species characteristic of the Upper Coal formation, while the horizon of this coal is believed to be in the lower part of the Middle Coal formation, or even in the Millstone-grit.

In my paper on Fossil Footprints,* I described from the Carboniferous rocks tracks referable to *Protichnites*, and which I regard as belonging to species of limulus, or horse-shoe crab, a genus which, though elsewhere known in the Carboniferous, has not been found in Nova Scotia, unless represented by these tracks. Other markings on the Carboniferous beds are impressions of worms, referable to the genus *Arenicolites*, and of crustaceans (trilobites or their allies) referred to genus *Rusichnites*. A very peculiar and anomalous form of large size was placed in the new genus *Diplichnites*, and the genus *Rabdichnites* was established to contain some markings resembling the so-called *Eophyton* of the Cambrian rocks, and probably of similar nature. Illustrations of these are given in Fig. 9.

Fig. 10. — *Carapace of Anthracopalæmon (Palæocarabus) Hillianum.* —Dawson.



The curious fossil figured in Fig. 10, the carapace or body shield of a species of *Palæocarabus*, was found by Mr A. J. Hill at the South Joggins, and is the first of the higher or decapod crustaceans found in our Coal formation. Very similar species occur in the Coal-fields of Great Britain and Illinois. It has been described in the Geological Magazine.†

The sole species of myriapod recognised by me in the original discovery of these animals at the Joggins was *Xylobius Sigillariæ;* but when a large number of fragments had accumulated in my collection, suggesting diversity of species, I placed the whole in the hands of Mr S. H. Scudder, our best

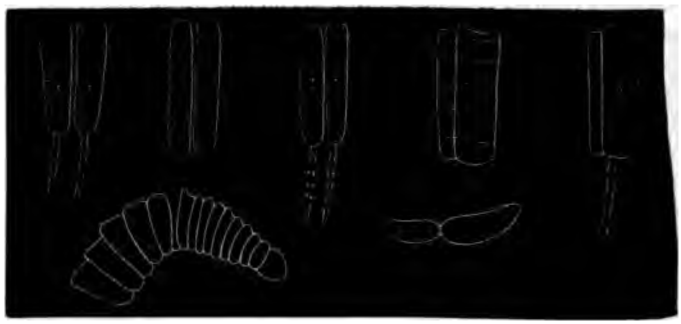
* Silliman's Journal, January 1873.

† February 1877.

authority on fossil insects, and he was able to discriminate two gener and five species. This was stated in a note at page 405 of Acadia Geology, and I now give a series of diagrammatic illustration prepared by Mr Scudder, showing the characteristic forms of the segments in the several species (Fig. 11.)

Fig. 11.—*Myriapods from the Coal Formation of Nova Scotia.*—After Scudder.

a b c d e



f g

(*a*) Two Segments of Xylobius Sigillariæ, Dawson.
(*b*) " " " X. similis, Scudder.
(*c*) " " " X. farctus, "
(*d*) One Segment of Archiulus Dawsoni, Scudder.
(*e*) " " " A. xylobioides, "
(*f*) Anterior Segments of " "
(*g*) Antennæ, Joints of " "

The remarkable discovery of Carboniferous batrachians made the South Joggins in 1876, in one of those erect trees which hav since 1851, afforded so many similar remains, is of so much intere in connexion with the species described in Acadian Geology, that make considerable extracts from the account of it published at the tim

The tree of 1876 was found by me in "the reef," or extension the sandstone seaward, and near the low-water mark. The upp part of the stump, probably filled with sandstone, had been remov by the waves, but about 2 feet of the lower part remained. It w extracted with as much care as possible by two miners with picks a crowbar, and the disk-like fragments, into which it naturally spl were carried up to the foot of the cliff, and subsequently numbe and dissected at leisure. In the hurry of working against time escape the tide, the men, it seems, left in the hole a portion of lowest layer, and a fragment of an upper one. The former was af wards removed by Mr J. C. Russel, of Columbia College, New Yo and the latter was found by Mr Hill. Both have been kindly pla in my hands by these gentlemen, so that the whole of the mate

has been collected and carefully labelled, in such a manner as to keep together the parts belonging to each skeleton.

This tree was about 18 inches in diameter, and in the lower part was partially flattened by lateral pressure, so that its diameter in one direction was only a little over a foot. The material filling the somewhat thick coaly bark may be described as a more or less arenaceous silt or soil, blackened with vegetable matter, and replete with fragments of carbonized bark, mineral charcoal, and fine vegetable debris. There are also numerous leaves of *Cordaites*, and abundance of the fruits which, from their frequent occurrence in such hollow trees, I have elsewhere named *Trigonocarpum Sigillariæ*. In some places the sediment was finely laminated, the laminæ being often much contorted. In other places the earthy matter existed in patches or interrupted layers, nearly free from vegetable matter, and especially abundant toward the sides of the trunk. The cementing substance is in general carbonate of lime, many portions of the mass effervescing freely with an acid, but in some spots there are hard concretions of pyrite. The material has evidently been introduced gradually, in small quantities at a time, and the earthy matter seems to have run down the sides, spreading more or less towards the centre, but in general accumulating around the circumference. The number of skeletons recovered in a more or less complete state was no less than thirteen in all, belonging probably to six species, besides other bones contained in coprolites, and several millipedes, and shells of *Pupa Vetusta*, the latter almost entirely in the lowest layers.

The first animal introduced was a specimen of *Hylerpeton Dawsoni*, Owen, whose bones and scutes, after decay of the connecting parts, had slid down the slope of silt from one side toward the centre of the space. Next, after a few inches of filling, came a specimen of *Dendrerpeton Acadianum*, Owen, whose bones lie along the centre of the layer and nearly in one plane. Above this a large flake of bark had fallen in, forming an imperfect floor over the remains. Then, after an inch or two of carbonaceous matter had been deposited, came a somewhat flat surface, which seems to have remained uncovered for some time, and on this lie the *disjecta membra* of three skeletons belonging to *Dendrerpeton Acadianum*, *D. Oweni*, and a new species of *Hylerpeton*. Above this was a confused mass of considerable thickness, in which were found another specimen of the new *Hylerpeton*, and remains representing a third animal of the same or an allied genus, also four specimens of *Hylonomus Lyelli*, and portions apparently of an immature *Dendrerpeton*. Still higher in position was a layer with large portions of the cuticle of a *Dendrerpeton*, probably

the species *D. Acadianum;* and above this, at the surface of the st were some remains and impressions of bones probably indica another specimen of *Dendrerpeton.* Taking these specimens in order above given, we may notice the new facts which they have closed on a preliminary examination.

2. *Remains of Hylerpeton.*

The sole species of this genus heretofore known, *H. Dawsoni,* discovered by me in 1860, and was described by Professor Owen fr remains so scanty that he expressed considerable doubt as to affinities. I afterwards worked out, from a few fragments of t matrix, the evidence that its teeth were simple, without plicated de tine, that it had a large canine or tusk in the anterior part of t upper jaw, and that it possessed a walking foot. The present spec men throws much additional light on its structure. It had at lea twelve teeth in each ramus of the mandible, and they are large i proportion to the size of the animal, bluntly conical and somewh acuminate, and faintly striate at the apex. The vomerine bones a beset with numerous small blunt teeth. The skull is long, and it bones thin and marked merely with delicate incised lines rather tha wrinkles. The forms of the stout ribs and scattered vertebræ woul indicate that the body was broad and squat. The skull must hav been about 2 inches in length, the body probably 4 or 5, an there are some small vertebræ which may indicate a short tail. Th limbs were large and strong, the femur being an inch and a quart long, and its shaft a fifth of an inch in diameter, and with thick bon walls. The vertebræ are short and biconcave, and with large dors spines, the belly was protected by numerous imbricated bony scal of two kinds, one oblong and narrow, the other broad and obliquel shield-shaped. There are indications of thoracic plates of larger si than the scales. On the whole, this species was probably a somewh clumsy creature, of toad-like form and slow gait, and with a denta apparatus suited to pierce and crush crusts and shells. It is perha significant of its habits, in these respects, that the layers of this t in which its bones occur are alone those in which shells of *Pu vetusta* are found.

The second species of *Hylerpeton,* which I may provisionally na *H. longidentatum,* was of somewhat smaller size, with the bones of skull thinner and more slender, and the teeth very long sharply pointed, with the apex finely striate, but with no corruga of the dentine. The vomer is covered with minute teeth, and t are long and slender anterior teeth, resembling canines. The

preserved mandible shows eighteen teeth, which are strongly inclined backward. The scales are very narrow, and there is a large thoracic plate. The general form of body may have been as in the last species, but the skull was probably narrower and the feet longer.

Another species of this genus, or belonging to a genus intermediate between it and *Hylonomus*, is represented by a confused mass of bones showing long and narrow jaws, armed with short and blunt teeth, of which at least thirty occur on each side of the lower jaws. The sculpture of the bones is as in the previous species, but the pulp-cavities of the teeth are smaller and their walls stronger, and they show no sculpture on the apex; in which respects they resemble those of *Hylonomus*. The vertebræ also are more elongated, and the femur is a large bone indicating a powerful hind limb. The abdominal scutes are very long and narrow, resembling slender semicylindrical rods, a point in which this species differs from all the others found with it, although it resembles some of those found in Ireland and Ohio. This species I would name provisionally, in allusion to the form of its teeth, *Hylerpeton curtidentatum*.

In all these species of *Hylerpeton* the teeth are simple, and are anchylosed to the bone and placed in linear series in a shallow groove.

3. *Remains of Dendrerpeton.*

The remains of this genus will afford additional facts as to the differences in individuals of various ages, and as to the details of the skeleton in the species *D. Oweni*, previously known by only one imperfect example. The specimen now found would seem to show that it resembled very much the larger species, except in the form of the teeth and scales. But the most interesting facts presented by a cursory examination of the specimens relate to the skin and its appendages. It is now evident that in addition to the abdominal and gular scales, *Dendrerpeton* possessed thoracic plates of considerable size, resembling those of other labyrinthodonts. The large mass of skin found in the tree of 1876, taken in connection with the smaller portions found on previous occasions, and described in detail in my "Air-breathers of the Coal-period," enables us to form a very good general idea of the appearance and clothing of the animals of this genus. To the naked eye the skin presents a shining and strongly rugose surface, reminding one of that of modern newts when contracted by immersion in alcohol, though on a coarser scale. Under the lens, the surface appears granular, and with a higher power the granulation is seen to result from minute scales embedded in the cuticle, and much smaller

than those, in previous finds, which I have referred to *D. Ou* to *Hylonomus*. On some portions of it there are delicate tra lines about a quarter of an inch apart, and apparently corresp to those which on the newts and Menobranchus mark the ba subcutaneous muscles. The bony scales of the abdomen hav appeared, except a few scattered in the matrix. But the remarkable dermal appendages are those triangular lappets or of which I have in previous papers described detached example have compared them with the gular and cervical lappets and fri iguanas, geckos, and Draco; and which also suggest analogies the processes that support the gills in perennibranchiate batrach and with the lateral folds of the skin in Menopoma. These app ages are flat and of appreciable thickness, about half an inch in le and an eighth of an inch in breadth, terminating in an edge or ol flat point, which seems to have been horny, while the appen itself must have been flexible. They are marked with small s oval areoles or projections, placed somewhat in rows, and each a minute puncture in its centre. The markings on both sides similar. These appendages are arranged in series along what app to be the skin of a fore leg, and also in groups apparently on the terior part of the body, perhaps the neck or shoulder. They ap to be closely connected with a series of much smaller angular p which extend along the edge of the skin near the supposed leg, probably fringe the sides of the abdomen. The evidence that integument belongs to *Dendrerpeton Acadianum* is derived from presence in its anterior part of skull-bones having the marking that of this species, and from the occurrence of a jaw and other b in the neighbouring matrix. The specimen to which the skin longed may have been about a foot in length. Taking it in con tion with what is known of the skeleton, we can reproduce the ext appearance of the animal. It was lizard-like in form, with a s what flat and broad head, and strong teeth with folded dentine. back was covered with a shining skin filled with microscopic h scales. Its sides were marked with vertical bands separated by del indented lines. Anteriorly it was ornamented with numerous cu ous lappets or pendants. The sides were bordered with a r sharp horny points, and the throat, thorax, and abdomen were prot by bony scales and plates, the scales of the throat being narro small, and arranged in a chevron pattern.

Dendrerpeton Oweni probably had the scales of the back an horny appendages larger in proportion, that is, if I have r referred to that species some similar remains to those above

tioned, found in 1859. *Hylonomus Lyelli* had a far more ornate set of cutaneous appendages, as evidenced by remains of skin found associated with its bones, also in 1859.* The tree of 1876 contains no cuticular remains referable to this species.

4. *Remains of Hylonomus.*

The bones of this genus are all, I think, referable to *H. Lyelli*, and to specimens about the size of those previously found. They throw little additional light on its character, except to indicate that it was probably very abundant, and to render it probable that the specimens formerly described were adult. Two of the skulls in the tree of 1876 are better preserved than those previously known, and confirm the statement already made as to the smoothness of the bones and the greater cranial elevation as compared with other batrachians of the Carboniferous period. This is indicated, among other things, by the skulls lying upon one side, which is not found to be the case with the other species.

In the admirable Report by Cope on the Batrachians of the Coal formation of Ohio,† he places *Hylonomus* in the same family, *Tuditanidæ*, with *Dendrerpeton*. This I think does not express its true affinities. The more elongate and narrow skull, with smooth bones, the differently formed vertebræ, the teeth with non-plicated dentine, the different microscopic structure of the bone, the more ornate dermal appendages, all separate these animals from the labyrinthodonts, and entitle them, as I have formerly held, to a distinct position as an order or sub-order, for which I proposed in 1863 the name *Microsauria*. I observe that in the Report on the Labyrinthodonts, prepared by Mr Miall for the British Association in 1873, and in the Tabular View appended to it in 1874, while the group *Microsauria* is retained, *Dendrerpeton* is placed in it, as well as *Hylerpeton* and *Hylonomus*. This I think is an error, in so far as the first genus is concerned. I may add my continued conviction that *Hylonomus* and its allies present many points of approach to the lacertian reptiles, which I hope in future to be able to work out more in detail.

Several masses of coprolite, filled with small broken bones, were obtained in breaking up the material surrounding the skeletons. I presume these bones belong to one or other of the smaller species of *Hylonomus*; but I have not yet found any of them to be sufficiently

* Journal Geol. Soc., vol. xvi., also "Air-breathers," 1863.
† Palæontology of Ohio, vol. ii.

characteristic to warrant any confident statement on the s These coprolites must have been produced by *Dendrerpe* *Hylerpeton*, most probably the former.

In the summer of 1877 Mr Hill kindly extracted for me other trees which had appeared in the reptiliferous bed, but proved barren of reptilian remains, though affording some c fossil plants. A fourth, which presented great difficulties i extraction, being 2½ feet in diameter, and embedded in stone to the height of 8 feet, was taken out for me in the summer. It afforded only one skeleton of *Dendrerpeton* and tached bones of *Hylonomus*, but was interesting as showing on layer the trails and tracks left by a reptile dragging itself arounc sides of the hollow tree in its efforts to escape. The details o these discoveries I hope to give to the public so soon as I can time to study fully the bones and teeth obtained.

I think it quite possible that further examination may enlarge number of species above mentioned. I have been guided mainl the reference of the specimens to species by the structure of the t and the cranial bones; but some of these may yield new point difference on further study. As all the specimens are preserved u the same conditions, there is less liability here than in most c to multiply species unduly, in consequence of different state preservation.

The fact that Cope has been able to catalogue, in his recent Rep 39 genera of Carboniferous batrachians, including about 100 spe and that these present so wide a range of size, structure, and gen conformation, affords a very remarkable illustration of that si taneous occurrence of many forms of one type, which appears i many other groups of fossil animals; and is particularly strikin this first known group of air-breathing vertebrates, which since l have swarmed upon us from the Coal-fields of both continents, an which we probably know as yet but a small fraction of the spe It remains to be seen whether the Devonian, so rich in its land f and which has already afforded remains of insects, may not dis some precursors of the Carboniferous batrachians.

Since the publication of the second edition, some very intere discoveries of footprints of Carboniferous reptiles have occ The most important of these is that originally made by Mr A J. Hill, C.E., at Fillimore's quarry, near River Philip. At this certain beds of brownish red sandstone hold numerous footprint large batrachian, now in the collection of the Geological Sur

* Palæontology of Ohio, vol. ii.

Canada, and which has been described by Mr Selwyn and myself.* The dimensions of the footprints are—

Hind foot, breadth	2·71 inches.
„ „ length	4·24 „
Fore foot, breadth	2·63 „
„ „ length	2·77 „
Length of stride	11·53 „
Average distance between the rows of foot-prints made by right and left feet .	5·48 „

These measurements correspond very nearly with those of my *Sauropus Sydnensis*.†

The hind foot, it will be observed, is considerably longer than the fore foot, and has a sort of plantigrade appearance; and there are some indications which show that the legs must have been strong and thick.

The hind foot shows four well-developed toes, the three outer stronger than the remaining one. There was also a fifth toe, which must have been placed at a higher level than the others, on the outside of the foot. It bore a long claw, which was plunged into the mud at each step, and when the foot was raised made a curved trace on the surface. It probably corresponded to the thumb-like fifth toe of labyrinthodon, and to the detached outer toe of the foot-prints figured by Sir C. Lyell. The fore foot is as broad as the hind foot, but much shorter, and shows four strongly-marked toes, with more obscure impressions of a fifth.

All the toes of both feet are broad in front, and seem to have had claws, but not of great length, except in the case of the detached toe of the hind foot above referred to. There is no indication of a membrane connecting the toes.

The prints of the hind and fore feet of each side are in a line, and the distance between the right and left lines, say 5½ inches, indicates a body broad in comparison with the length of the legs.

The impression of the hind foot is either a little way behind that of the fore foot, or the impressions are equidistant, indicating a walking gait varying somewhat in the length of the stride.

There are no indications of a tail, and in general the body was carried clear of the ground; but in one place it has been dragged along the surface, leaving longitudinal furrows, probably indicating that the abdomen was clothed with bony scales, as was generally the case

* Geol. Magazine, vol. ix. † Acadian Geology, p. 358.

in the labyrinthodonts of the Carboniferous. On another slab seems to have been a soft place where the legs of the animal sunk deeply into the mud; and it would appear to have been m extricating itself with some difficulty, and leaving deep marks of body and legs.

These footprints must have been made on a subaerial surface, p ably left dry by the recession of the tide, and rain must have fa shortly before the animal passed over it, as indicated by the pi appearance of the slabs. The trunk of the creature may have b 3 feet in length. Its tail, if it had such an appendage, must h been short, or carried in the air without touching the ground. legs were strong, and bore the body well above the surface w walking. The only known Carboniferous batrachian of Nova Sc which could have made these impressions is *Baphetes planic* Owen, discovered by the author in the Coal-field of Pictou. *Eosau Acadiensis* of Marsh, from the Joggins, was a creature of suffici size, but probably of different structure, and more exclusively aqu habits.

The principal distinctive character of the present specimens is peculiar appendage on the hind foot, and from this we may give provisional name *Sauropus unguifer* to these footprints, until animal which produced them shall be known to us by its bones.

It is interesting that in three localities in Nova Scotia, and two Pennsylvania, footprints of this general type and of the same s have been found, indicating the wide diffusion and abundance of th large batrachians in the Carboniferous period in North America, also that they were animals comparable in size and development limb with some of their successors in the Mesozoic period.

One of the slabs in the rooms of the Survey shows a number of l distinct footprints of an animal which may have been two-third the size of that above described, though possibly of the same spec In the Provincial Museum of Halifax there is a slab with a series footprints similar to these. Dr Honeyman has also placed in same Museum a series of footprints, of the Dendrerpeton type, f Great Village River.

On another slab, and associated with the larger footprints, are s small trifid impressions which seem to indicate the presence of a smaller animal, with feet of different form from those of the otl These small trifid footprints are not dissimilar from those foun Sir W. E. Logan, at Horton, in 1841, and which were the indications of reptilian life discovered in the Carboniferous. are also allied to those subsequently discovered by Dr Hardir

Parsboro', and by myself at the Joggins, and referred to in Acadian Geology. These smaller footprints, showing marks of three toes, and in more distinct impressions of four or five, I have conjectured may have been produced by Labyrinthodonts of the type of *Dendrerpeton*.

Origin of Coal.

The readers of recent English popular works on geology will have observed the statement reiterated, that a large proportion of the material of the great beds of bituminous coal is composed of the spore-cases of lycopodiaceous plants—a statement quite contrary to that resulting from my microscopical examinations of the coal of more than eighty Coal-beds in Nova Scotia and Cape Breton, as stated in Acadian Geology (page 463), and more fully in my memoir of 1858 on the Structures in Coal,* and that of 1866 on the Conditions of Accumulation of Coal.† The reason of this mistake is that an eminent English naturalist, happening to find in certain specimens of English coal a great quantity of remains of spores and spore-cases, though even in his specimens they constitute only a small portion of the mass, and being apparently unacquainted with what others had done in this field, wrote a popular article for the Contemporary Review, in which he extended an isolated and exceptional fact to all coals, and placed this supposed origin of coal in a light so brilliant and attractive that he has been followed by many recent writers. The fact is, as stated in Acadian Geology, that trunks of *Sigillariæ* and similar trees constitute a great part of the denser portion of the coal, and that the cortical tissues of these rather than the wood remain as coal. But cortical or epidermal tissues in general, whether those of spore-cases or other parts of plants, are those which from their resistance to water-soakage and to decay, and from their highly carbonaceous character, are best suited to the production of coal. In point of fact, spore-cases, though often abundantly present, constitute only an infinitesimal part of the matter of the great Coal-beds. In an article in Silliman's Journal, which appeared shortly after that above referred to, I endeavoured to correct this error, though apparently without effect in so far as the majority of British geological writers are concerned. From this article I may quote the following passages, as it is of importance in theoretical geology that such mistakes, involving as they do the whole theory of coal accumulation, should not continue to pass current. The early part of the paper is occupied

* Journal Geol. Society, vol. xv. † *Ibid.*, vol. xxii.

with facts as to the occurrence of spores and spore-cases as partial ingredients in coal. Its conclusions are as follows :—

"It is not improbable that sporangites, or bodies resembling them, may be found in most coals; but the facts above stated indicate that their occurrence is accidental rather than essential to coal accumulation, and that they are more likely to have been abundant in shales and cannel coals, deposited in ponds or in shallow waters in the vicinity of lycopodiaceous forests, than in the swampy or peaty deposits which constitute the ordinary coals. It is to be observed, however, that the conspicuous appearance which these bodies and also the strips and fragments of epidermal tissue, which resemble them in texture, present in slices of coal, may incline an observer, not having large experience in the examination of coals, to overrate their importance; and this I think has been done by most microscopists, especially those who have confined their attention to slices prepared by the lapidary. One must also bear in mind the danger arising from mistaking concretionary accumulations of bituminous matter for sporangia. In sections of the bituminous shales accompanying the Devonian coal above mentioned, there are many rounded yellow spots, which on examination prove to be the spaces in the epidermis of *Psilophyton* through which the vessels passing to the leaves were emitted. To these considerations I would add the following, condensed from my paper above referred to, in which the whole question of the origin of coal is fully discussed :*—

"(1.) The mineral charcoal or 'mother coal' is obviously woody tissue and fibres of bark, the structure of the varieties of which, and the plants to which it probably belongs, I have discussed in the paper above mentioned.

"(2.) The coarser layers of coal show under the microscope a confused mass of fragments of vegetable matter belonging to various descriptions of plants, and including, but not usually largely, sporangites.

"(3.) The more brilliant layers of the coal are seen, when separated by thin laminæ of clay, to have on their surfaces the markings of *Sigillariæ* and other trees, of which they evidently represent flattened specimens, or rather the bark of such specimens. Under the microscope, when their structures are preserved, these layers show cortical tissues more abundantly than any others.

"(4.) Some thin layers of coal consist mainly of flattened layers of leaves of *Cordaites* or *Pychnophyllum*.

"(5.) The *Stigmaria* underclays and the stumps of *Sigillaria* in the

* See also Acadian Geology, 2d edit., pp. 138, 461, 493.

coal roofs equally testify to the accumulation of coal by the growth of successive forests, more especially of *Sigillariæ*. There is, on the other hand, no necessary connection of sporangite beds with Stigmarian soils. Such beds are more likely to be accumulated in water, and consequently to constitute bituminous shales and cannels.

"(6.) *Lepidodendron* and its allies, to which the spore-cases in question appear to belong, are evidently much less important to coal accumulation than *Sigillaria*, which cannot be affirmed to have produced spore-cases similar to those in question, even though the observation of Goldenberg as to their fruit can be relied on; the accuracy of which, however, I am inclined to doubt.

"On the whole, then, while giving due credit to Prof. Huxley and those who have preceded him in this matter, for directing attention to this curious and no doubt important constituent of mineral fuel, and admitting that I may possibly have given too little attention to it, I must maintain that Sporangite beds are exceptional among coals, and that cortical and woody matters are the most abundant ingredients in all the ordinary kinds; and to this I cannot think that the coals of England constitute an exception.

"It is to be observed, in conclusion, that the spore-cases of plants, in their indestructibility and richly carbonaceous character, only partake of qualities common to most suberous and epidermal matters, as I have explained in the publications already referred to. Such epidermal and cortical substances are extremely rich in carbon and hydrogen, in this resembling bituminous coal. They are also very little liable to decay, and they resist more than other vegetable matters aqueous infiltration,—properties which have caused them to remain unchanged, and to resist the penetration of mineral substances more than other vegetable tissues. These qualities are well seen in the bark of our American white birch. It is no wonder that materials of this kind should constitute considerable portions of such vegetable accumulations as the beds of coal, and that when present in large proportion they should afford richly bituminous beds. All this agrees with the fact, apparent on examination of the common coal, that the greater number of its purest layers consist of the flattened bark of *Sigillariæ* and similar trees, just as any single flattened trunk embedded in shale becomes a layer of pure coal. It also agrees with the fact that other layers of coal, and also the cannels and earthy bitumens appear, under the microscope, to consist of finely comminuted particles, principally of epidermal tissues, not only from the fruits and spore-cases of plants, but also from their leaves and stems. These considerations impress us, just as much as the abundance of spore-cases,

with the immense amount of the vegetable matter which has peri
during the accumulation of coal, in comparison with that which
been preserved.

"I am indebted to Dr T. Sterry Hunt for the following very v
able information, which at once places in a clear and precise light
chemical relations of epidermal tissue and spores with coal.
Hunt says—'The outer bark of the cork tree, and the cuticle of m
if not all other plants, consists of a highly carbonaceous matter,
which the name of *suberin* has been given. The spores of *Lycopodi*
also approach to this substance in composition, as will be seen by t
following, one of two analyses by Duconi,* along with which I gi
the theoretical composition of pure cellulose or woody fibre, accordi
to Payen and Mitscherlich, and an analysis of the suberin of cor
from *Quercus Suber*, from which the ash and 2·5 per cent. of cellulo
have been deducted.†

	Cellulose.	Cork.	Lycopodium.
Carbon, . .	44·44	65·73	64·80
Hydrogen, . .	6·17	8·33	8·73
Nitrogen, . .	...	1·50	6·18
Oxygen, . .	49·39	24·44	20·29
	100·00	100·00	100·00

"'This difference is not less striking when we reduce the abo
centesimal analyses to correspond with the formula of cellulos
$C_{24} H_{20} O_{20}$, and represent cork and *Lycopodium* as containing 2
equivalents of carbon. For comparison I give the composition
specimens of peat, brown coal, lignite, and bituminous coal.‡

Cellulose, ...	$C_{24} H_{20} O_{20}$
Cork, ...	$C_{24} H_{18\frac{2}{10}} O_{6\frac{7}{10}}$
Lycopodium, ...	$C_{24} H_{19\frac{4}{10}} NO_{5\frac{6}{10}}$
Peat (Vaux), ...	$C_{24} H_{14\frac{4}{10}} O_{10}$
Brown Coal (Schröther), . .	$C_{24} H_{14\frac{3}{10}} O_{10\frac{6}{10}}$
Lignite (Vaux), ...	$C_{24} H_{11\frac{2}{10}} O_{6\frac{4}{10}}$
Bituminous Coal (Regnault), . .	$C_{24} H_{10} O_{3\frac{3}{10}}$

"'It will be seen from this comparison that, in ultimate compo
tion, cork and *Lycopodium* are nearer to lignite than to woo
fibre; and may be converted into coal with far less loss of carbon a
hydrogen than the latter. They in fact approach closer in compo
tion to resins and fats than to wood, and, moreover, like those su
stances repel water, with which they are not easily moistened, a

* Liebig and Kopp, Jahresbuch, 1847-48. † Gmelin, Handbook, xv. 14
‡ Canadian Naturalist, vi. 253.

thus are able to resist those atmospheric influences which effect the decay of woody tissue.'

"I would add to this only one further consideration. The nitrogen present in the *Lycopodium* spores, no doubt, belongs to the protoplasm contained in them, a substance which would soon perish by decay; and subtracting this, the cell-walls of the spores and the walls of the spore cases would be most suitable material for the production of bituminous coal. But this suitableness they share with the epidermal tissue of the scales of strobiles, and of the stems and leaves of ferns and lycopods, and above all, with the thick corky envelope of the stems of *Sigillariæ* and similar trees, which, as I have elsewhere shown,* from its condition in the prostrate and erect trunks contained in the beds associated with coal, must have been highly carbonaceous and extremely enduring and impermeable to water. In short, if instead of 'spore-cases,' we read 'epidermal tissues in general, including spore-cases,' all that Huxley has affirmed will be strictly and literally true, and in accordance with the chemical composition, microscopical characters, and mode of occurrence of coal. It will also be in accordance with the following statement, from my paper on the Structures in Coal, published in 1859:—

"'A single trunk of *Sigillaria* in an erect forest presents an epitome of a coal-seam. Its roots represent the *Stigmaria* underclay; its bark the compact coal; its woody axis the mineral charcoal; its fallen leaves (and fruits), with remains of herbaceous plants growing in its shade, mixed with a little earthy matter, the layers of coarse coal. The condition of the durable outer bark of erect trees concurs with the chemical theory of coal, in showing the especial suitableness of this kind of tissue for the production of the purer compact coals. It is also probable that the comparative impermeability of the bark to mineral infiltration is of importance in this respect, enabling this material to remain unaffected by causes which have filled those layers, consisting of herbaceous materials and decayed wood, with pyrites and other mineral substances.'"

8. THE DEVONIAN.

On the distribution and arrangement of the rocks of this period I have nothing material to add to what I have already stated in referring to the Geological Map. Though the Devonian does not occupy a very wide area in the Acadian Provinces, yet, in connection with the neighbouring areas in the province of Quebec, it is of great in-

* Vegetable Structures in Coal, Jour. Geol. Soc., xv. 626. Conditions of Accumulation of Coal, *ib.*, xxii. 95. Acadian Geology, 197, 464.

terest, as showing perhaps more of the land life of the per more especially of its flora, than the Devonian of any other pa world. In connexion with this, it is to be observed that t development of this formation in the great Lake Erie distric mainly its marine conditions. Yet it is satisfactory to kn Professor Hall finds erect trunks of tree-ferns and abund remains of fern fronds and *Psilophyton* in the Chemung sands New York, and that in the marine limestones of Ohio Dr Ne has discovered trunks of conifers and beautifully preserved stems ferns. The vague notions which many European geologists stil tain as to the importance and extent of the Devonian period w at once corrected could they study the American development

The following table will show the nature and distribution formations referred to:—

Devonian, or Erian of America.

Subdivisions.	New York and Western Canada.	Gaspé.	Southern New Br and Nova Sco
Upper Devonian or Erian.	Chemung Group.	Upper Sandstones. Long Cove, etc.	Mispec Group. Shale, Sand and Conglon Sandstones Middle R., P
Middle Devonian or Erian.	Hamilton Group.	Middle Sandstones. Bois Brulé, Cape Oiseau, etc.	Little R. Grou cluding Co shales and doxylon Sands
Lower Devonian or Erian.	Corniferous and Oriskany groups.*	Lower Sandstones. Gaspé Basin, Little Gaspé, etc.	Lower Congl merates, et Nictaux and River Serie (Oriskany)

These rocks in the Acadian Provinces overlie the fossiliferou of the Lower Helderberg or Ludlow group, and underlie the Carboniferous, to the peculiar flora of which I have already re From these beds, thus limited, I have described or catalogue species of fossil plants,† of which the greater part are specificall some generically, distinct from those of the Lower Carboni A very considerable proportion of these plants have been d

* On the evidence of fossils, Hall now regards the Oriskany as Silurian really a group of transition, and in Canada its physical relations are with the D and it introduces the fauna and flora of that age.

† Report on Fossil Plants of Devonian, etc., Geological Survey of Canada,

from the rich plant-bearing beds near St John, New Brunswick, so admirably explored by Messrs Hartt and Matthew. It is proper, however, to explain that, in Acadian Geology, I have restricted myself to these species, not noticing, except incidentally, those from the Devonian of Gaspé, New York, etc. It is also to be observed that several of the species mentioned in that work are much more fully

Fig. 12.—*Psilophyton princeps.*—Restored.

a, Fruit, natural size; *b*, Stem, natural size; *c*, Scalariform tissue of the axis, highly magnified
In the restoration, one side is represented in vernation, and the other in fruit.

illustrated and described in the Report above referred to. More especially is this the case with the remarkable genus *Psilophyton*, the fructification of which was not distinctly known when my last edition was published, but will be found fully described and figured in the

Report. The restoration given in Fig. 12 will better show the character of this curious plant, which, while allied to the club-in structure and habit, has remarkable peculiarities in its fructifi In the case of *P. elegans*, in which* the fructification is s consist of "oval scales," these should be understood as fla spore-cases, not scales. *Cyclopteris Jacksoni* would also no placed in my new genus *Archæopteris;* and, as previously under the head of Carboniferous, a higher place in the vege kingdom might now be assigned to the genus *Cordaites* on the dence furnished by M. Grand 'Eury.

The disposition which prevails among European palæobotanis refer our Devonian flora to the Lower Carboniferous, proceed already pointed out, in part from their imperfect acquaintance wit development of this system of formations in America, and also the superior richness, so far, of our flora. But there is not imp ably another reason. Just as the modern genera of plants see have appeared in full force in America in the Cretaceous, whil Europe they scarcely attain a similar development till the Mio Tertiary, we may have had an earlier introduction of the Palæ flora. This is, I think, now rendered probable by the later pub tions of Stur and Heer. In any case, however, our Devonian flo markedly distinct from that of the Lower Carboniferous, as ma seen by reference to the Reports on those floras already referred

9. THE UPPER SILURIAN.

In the Acadian Provinces, as in some other parts of Ea America, the great igneous outbursts, evidenced by the masses dykes of granite which cut the Lower Devonian rocks, make a st line of distinction between the later and older Palæozoic. Whil Carboniferous series is unaltered, except very locally, and com tively little disturbed, and confined to the lower levels, the U Silurian, and all older series, have been folded and disturbed profoundly altered, and constitute the hilly and broken parts c country. Further, in the Upper Silurian and the older periods, seems to have been a constant mixture with the aqueous sedi in process of deposition of both acidic and basic volcanic mat the form of ashes and fragments, as well as probably outflc trachyte and dioritic rock, so that all these older formatio characterized by the presence of felsite, and porphyry, and siliceous breccia, and of diorite. Further, since these volcan

* Ac. Geol., 543.

tufaceous rocks, owing to their composition, are much more liable to be rendered crystalline by metamorphism than the ordinary aqueous sediments from which the bases have been leached out by water, and since they are usually not fossiliferous, the appearance is presented of crystalline non-fossiliferous rocks alternating with others holding abundant organic remains, and comparatively unaltered. The volcanic members of these series are also often very irregular in distribution, and there is little to distinguish them from each other, even when their ages may be very different. These circumstances oppose many difficulties to the classification of all the pre-Devonian rocks of Nova Scotia and New Brunswick, difficulties as yet very imperfectly overcome. My own attempts to unravel these intricacies have as yet been only partially satisfactory to myself, and I have seen quite as little reason to be satisfied with many of the arrangements which have been suggested by others. We shall, however, endeavour to ascertain what new facts are available, and to what extent they contradict or modify the views given in the text of Acadian Geology.

Messrs Bailey and Matthew have devoted much time and labour to the rocks which crop out from under the Upper Devonian beds at Perry in Maine, and extend thence eastward into New Brunswick, where they have been named the "Mascarene series." I studied these beds in 1862, as they occur at Pigeon Hill and elsewhere near Eastport, and referred them to the Upper Silurian period,* but the tracing of their extension in New Brunswick, and the full establishment of their age, belongs to the gentlemen above named.†

These rocks are extensively developed in the south-western part of New Brunswick, and their thickness has been estimated at 2000 feet. The following section, in ascending order, taken from the Report of the Geological Survey for 1875–6, shows the general structure of the formation in Queen's County.

Division 1.	Gray clay slates, mostly of pale colour and generally somewhat calcareous. Darker-gray clay slates, some of which are carbonaceous, ... about	400 feet.
Division 2.	Black and dark-gray argillaceous or silicious clay slates, with very regular sedimentary bands, ... about	600 ,,
Division 3.	Dark-gray and greenish-gray earthy sandstones, the lower part compact, the upper	

* Paper on Precarboniferous Flora.
† Reports, Geol. Survey, 1875-6.

part more slaty, greenish-gray, calcareous, or black and fissile, . . . about 600

Division 4. Ash-gray and greenish-gray schistose beds, generally chloritic and calcareous, sometimes amygdaloidal and dioritic, . . about 300

Division 5. Alternations of gray and dark-gray felsites (often porphyritic), with compact dark-gray feldspathic rock, clouded with green and purple, and with beds of dark and pale-green chloritic schist. There is a mass of felsite about 150 feet thick near the base, and a breccia conglomerate at the summit, . about 800 feet or m

These rocks, with the same general structure, are widely dis buted in Southern New Brunswick, but, as might be expected, th vary in detail, more especially in the upper members. They a present a general resemblance to the belt of Upper Silurian roc already referred to as extending towards Bathurst, and rocks of tl type are known to occur in the Upper Silurian districts of No Scotia.

The fossils found in the lower members of this series near Ea port are a *Lingula* allied to *L. centrilineata* of the Lower Helde berg, and also very near to some Hamilton species, and to that fou in the Lower Devonian of Gaspé, though probably different from th occurring in the Upper Silurian of Wentworth, Pictou, and Arisai There are also species of *Modiomorpha*, and a species of *Loxonem* with a small *Beyrichia* of Upper Silurian type. Elsewhere in Ne Brunswick these beds have afforded species of *Strophomena*, *Orth* *Rhynchonella*, *Pterinea*, and corals of Upper Silurian genera. The can thus be no doubt as to their general age, though we have n sufficient evidence to assign them to any particular horizon in t series of Upper Silurian beds known in Nova Scotia.

The Kingston group, referred in Acadian Geology to the Upp Silurian, is now regarded as in great part of older date, thou fossils apparently Upper Silurian have been found in some of beds. From the sections given by Bailey and Matthew, and t specimens I have seen, it is apparent that its rocks somewl resemble in mineral character those of the Mascarene seri They, however, also closely resemble the series of beds which, the Cobequid Mountains and East River of Pictou, is seen to eme from beneath the Upper Silurian series, and which is proba

Lower Silurian, and to which I shall in the sequel give the name of the Cobequid series, already applied to it in the Table of Formations in Acadian Geology.*

The cuttings of the Intercolonial Railway have enabled Dr Honeyman to recognise at Wentworth, on the north side of the Cobequids, the extension westward of the Upper Silurian rocks mentioned in Acadian Geology, and also in an earlier memoir on the Metamorphic rocks of Eastern Nova Scotia,† as flanking the crystalline rocks of these hills in New Annan and Earlton. Dr Honeyman was disposed to regard these beds at Wentworth as possibly as old as the Cincinnati group of the Lower Silurian; but the fossils which I have collected in them seem to me to indicate that they are probably of the age of the Lower Arisaig series,‡ or about that of the Clinton of New York. They also much resemble in mineral character the Lower Arisaig beds, as well as those of similar age near Cape Gaspé, and on the Matapedia. The more characteristic fossils in my collections are :—

Graptolithus Clintonensis, Hall.
Climacograpsus and Retiograpsus (?) sp.
Atrypa reticularis, Dalman.
Strophomena rhomboidalis, Wahl.
Lingula oblonga, Hall.
Orthis tenuiradiata, Hall, or allied.
Orthis elegantula, Dalman, or allied.
Rhynchonella neglecta, Hall, „
Leptocœlia intermedia, Hall, „
Tentaculites distans, Hall, „

As usual in the shales of this series, the finer markings of the shells are not well preserved, so that it is not easy to assign them to their species. I think, however, that I cannot be wrong in referring them to the lower part of the Upper Silurian.

At Wentworth the dark shales holding these fossils are traversed by diabase dykes,§ in the vicinity of which the shales have assumed a gray colour, and have been hardened so as in places to resemble felsites. It is probable that the fossiliferous beds may be unconformable to the hard slates, felsites, and porphyries underlying them, but the shales must have participated to some extent in the movements to which the older rocks have been exposed.

* Page 20. † Journal Geological Society, vol. vi.

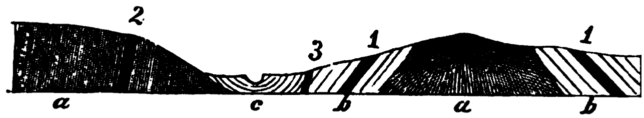
‡ I use the term "Lower Arisaig" in the sense attached to it in Acadian Geology, namely, for the lower fossiliferous series at that place, in the main equivalent to the Clinton and Medina groups of New York— Llandovery of England.

§ See Note IV. in Appendix.

Farther eastward, at French River and Waugh's River, the sentatives of the Wentworth series contain coarse limestoı hard sandstone as well as shale, but hold some of the same i and at Earlton loose pieces contain fossils of a somewhat l horizon equivalent to the Upper Arisaig series.

Passing from the eastern end of the Cobequids across a bay (Pictou Carboniferous area, we find well-characterized Upper Si rocks with fossils of the Upper Arisaig (Lower Helderberg) These rocks have recently been somewhat carefully examin connexion with explorations of the great deposits of iron ore ciated with them. It would seem that the upper half of the U Silurian is here quite as well developed as at Arisaig, and incl the great bed of fossiliferous hematite which is so characteristic of region (Fig. 13). From below these beds arise thick beds of f

Fig. 13.—*Ideal Section, showing the general relations of the Iron Ores of the E River of Pictou.*



1. Great bed of Red Hematite.
2. Vein of Specular Iron.
3. Vein of Limonite.

(*a*) Older Slate and Quartzite series, with Felsite and Ash Rocks, etc.
(*b*) Lower Helderberg formation and other Upper Silurian Rocks.
(*c*) Lower Carboniferous of the East Branch of East River.

ginous quartzite, and of imperfectly crystalline diorite and slaty an sitic breccias, which would seem to be lower members of the U Silurian, and which are less indurated than the rocks of similar com tion referred to the Lower Silurian and older series in the sequel. T latter rocks, which also appear in the vicinity of the East River breccia, felsite, quartzite, slates, and hydro-mica schists, which b close resemblance to the Cobequid series, and pass to the south and westward of the newer rocks, no doubt forming in this r the continuation of that formation. In the central parts of the at the head-waters of the East River, these beds are seen, as i Cobequids, to be invaded by great masses of an intrusive red sy

Eastward of the East River the continuation of the Upper Si rocks has been traced by Dr Honeyman all the way to A where their characteristics are fully described in Acadian Ge and beyond this as far as Lochaber Lake, where at least the members occur.

One of the most interesting fossils recently found in the Upper Silurian of Eastern Nova Scotia, is the complete specimen of *Homalonotus Dawsoni*, Hall, figured here (Fig. 14), and which was

Fig 14.—*Homalonotus Dawsoni.*—Hall. *Half natural size.*

(*a*) Margin of Segment.

found on the East River of Pictou by Mr D. Fraser, who has collected many of the characteristic fossils of this district while exploring its iron deposits.

We have to inquire under the next head as to those regions coloured in the map as Upper Silurian, but which subsequent investigations have relegated with some probability to older periods.

I have said nothing above of the areas of Niagara, Lower Helderberg, and Oriskany in the western counties, because I have not revisited them since the publication of my edition of 1868, and have no further facts to present. Farther study of the fossils formerly collected has not materially modified the conclusions stated in Acadian Geology, pp. 498, 499, and 571; but much remains to be done in this district.

10. THE LOWER SILURIAN.

In the second edition of Acadian Geology, following, though
protest, the Murchisonian nomenclature, then current both in Er
and America, and adopted by the Canadian Geological Surv
included under this head all the fossiliferous rocks older tha
Upper Silurian. If, however, we restrict the term Lower Siluri
that geological group of which the great Trenton formation in Am
and the Bala in England are the main and typical members, and w
contains what Barrande has called the "second fauna," then we
as yet no certainly determined fossiliferous group of this ag
Acadia; and there seems little doubt that the great Lower Silu
fossiliferous limestones are absent, as they appear also to be in N
foundland.* If, therefore, there are any representatives of the Lo
Silurian, we have to look for them in those rocks underlying
Upper Silurian series, and which are largely of the nature of volc
or trap-ash deposits.

In New Brunswick the band of old rocks lying on the north of
crystalline belt extending south-west from Bathurst, and compose
greenish felsites, quartzites, and slates of various kinds, is usu
referred to the Lower Silurian. The evidence of this is, first,
appearance from under the Upper Silurian beds in the same man
with the rocks of the Quebec group on the north; and, secondly,
occurrence of a few graptolites, found by Mr Robb, but as yet c
in loose stones. Lithologically these rocks may be regarded as
responding somewhat closely with portions of the Quebec group,
also with the contemporaneous Skiddaw and Borrowdale serie
England. According to Messrs Bailey and Matthew, similar ro
occur also in several places in the south-west of New Brunswick,
underlie the Upper Silurian of that region. If this view of their
is correct, then it would follow that the mixed aqueous and volc
deposits so characteristic of the Huronian recurred in the Lo
Silurian, and again in the deposition of the Upper Silurian Masca
series. On the evidence of mineral character, as well as of relatio
the Upper Silurian series, there seems some reason to suppose tha
Kingston group of Messrs Bailey and Matthew, occupying the pe
sula between Kennebecasis Bay and the St John River, and exten
south-westward to the coast, may also, as stated above, be of this

Crossing over to Nova Scotia, we have in the Cobequid Moun
a great series of slates, quartzites, and volcanic rocks, evidently u

* Murray's Geological Map, 1877.

lying the Wentworth series, but destitute of fossil remains. These, with their continuation in the district extending eastward from the Cobequids to the Strait of Canso and into Cape Breton, were characterized by me in 1850* as consisting of " various slates and quartzites, with syenite, greenstone, compact felspar, claystone, and porphyry," and were named in Acadian Geology the "Cobequid group," and their age defined as intermediate between that of the lower Arisaig fossiliferous series and the Gold series (Cambrian) of the Atlantic coast. As they had afforded no fossils, and as there seemed to be a lithological and stratigraphical connection between them and the lower part of the Upper Silurian, they were placed with that series as a downward extension, or, in part, metamorphosed members of it.

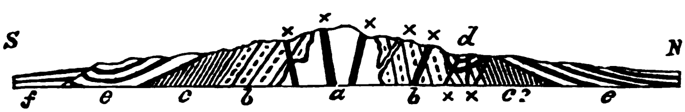
The arrangement of these rocks in the central part of the Cobequids, and also between the East River of Pictou and the east branch of the St Mary's River, may be stated thus. There is a central mass of red intrusive syenite or syenitic granite, usually having a large predominance of red orthoclase, with a moderate quantity of hornblende and quartz. This sends veins into the overlying beds, and is itself penetrated by dykes of diabase. On this central mass rests a great thickness of felsites, porphyries, felsitic agglomerates, and diorites, evidently of volcanic origin. Upon these are gray, black, and reddish slates and quartzites, with a bed of limestone, and penetrated by metallic veins. The lower volcanic portions and the upper more strictly aqueous parts might perhaps be separated as a Lower and Upper Cobequid series; but the difference appears to depend rather on mode of deposition than on any great difference of age.

Along the northern side of the Cobequids, and between Pictou and Arisaig, these beds are seen immediately to underlie the Upper Silurian rocks, which have been disturbed with them, and are penetrated by the same igneous dykes. Dr Honeyman appears to have observed the same relation on the Lochaber Lake and in other parts of Antigonish County. This somewhat constant association would seem to indicate that the rocks in question immediately underlie the Upper Silurian, and are therefore themselves of Lower Silurian age. On the other hand, their similarity in mineral character with the Huronian series of New Brunswick, with rocks observed in Cape Breton to rise from under Cambrian deposits, and with the Huronian rocks of Murray in Newfoundland, might induce us to assign them to an earlier date. There are, however, some differences in mineral character; as, for example, the greater prevalence of olive, black, and micaceous slates, and of highly felspathic rocks in the Cobequid series,

* Journal of Geological Society, vol. vi.

which, while they ally this series with that of Northern New Brunswi and of the Kingston peninsula, separate it from the typical Huronia I am therefore inclined to believe that it will ultimately be found th there are three barren series of mixed volcanic and aqueous deposi in the Acadian Provinces, separated by fossiliferous deposits, viz (1) The Huronian, over which lie the fossiliferous Cambrian (Acadian beds; (2) The Cobequid series, over which lie the fossiliferous Middl and Upper Silurian; (3) The Mascarene series, belonging to th Upper Silurian. In some districts, as in Southern New Brunswicl and Cape Breton, where these series, or some of them, approacl closely to each other, and are much disturbed, it may be difficult t disentangle these deposits; but I believe the distinction will be foun to hold good, and will no doubt be facilitated by the discovery o additional fossiliferous beds.

Fig. 15.—*General Structure of the Cobequid Range.*



(*a*) Massive Syenitic Granite.
(*b*) Lower Cobequid Series, Felsite, Porphyry, Agglomerate, &c.
(*c*) Upper Cobequid Series. Ferriferous Slates and Quartzite.
(*d*) Wentworth Fossiliferous Beds.—Upper Silurian.
(*e*) Carboniferous.
(*f*) Triassic.
(*x*) Veins of Syenite and Diabase.

In the meantime, I have no doubt of the identity of the greate part of the altered and volcanic beds of the hilly country extending through Pictou and Antigonish counties, and underlying the Uppe Silurian, with the Cobequid series. Further, large suites of specimens placed in my hands by Albert J. Hill, Esq., leave no room to doubt the similarity of the greater part of the rocks in the district extending from St Peter's to Scatari in Cape Breton to the Cobequid deposits; though, as will appear in the sequel, there is reason to believe that older rocks occur both in this district and in Northern Cape Breton.

Mr Selwyn, who has studied these rocks in Southern Cape Breton and in Eastern Nova Scotia, but has not yet published his results takes, I believe, similar views of their probable age, and compare their lithological character with that of the contemporaneous trap-asl beds and similar volcanic deposits in South Wales. Their resem blance to the Borrowdale and Skiddaw series in England, as describe by Ward in his Report on these formations, is also remarkable.

If the above views are correct, it will follow that in the Lower Silurian period the area of Nova Scotia and New Brunswick was the theatre of extensive and long-continued volcanic ejections, producing a series of rocks entirely dissimilar from those deposited at the same period in the interior continental region, though in some respects resembling those of Great Britain and those of the regions in Quebec and the United States lying east of the great Appalachian line of disturbance.

11. THE CAMBRIAN.

Under this head I would now place the interesting "Acadian series" of St John, so well characterized by its fauna, that it may be considered as the typical representative in Eastern America of that Middle or Lower Cambrian formation known in England as the Menevian, and of Barrande's étage C of the Primordial in Bohemia. The true horizon of these beds was, of course, perfectly recognised at the time of the publication of my last edition, but they were then, in accordance with prevailing classification, placed as Primordial Silurian. Nothing new can as yet be added to the almost exhaustive examination of their fossils at that time made by Professor Hartt, nor has the area of beds holding these fossils in the Acadian Provinces been considerably extended.* In Newfoundland† and New England, however, beds of this age seem to have a large extension; and in certain conglomerates of the Quebec group on the Lower St Lawrence there are fragments holding the remains of a fauna which has been termed by Billings Lower Potsdam, and must be near to the age of the Acadian group.

The great Atlantic coast series of Nova Scotia, which is the auriferous formation of that province, and includes in ascending order the so-called Quartzite and Clay-slate formations, in which these rocks respectively predominate, I believe to be likewise Cambrian or Primordial, a view which Mr Selwyn and Professor Hind have also advocated. It is, however, noteworthy that in mineral character this very widely extended formation does not precisely resemble the Acadian series of New Brunswick, and it is therefore to be presumed that it represents some other part of that great system of formations.

The evidence of fossils in determining the precise age of these rocks is unfortunately as yet somewhat imperfect. Mr Selwyn has recognised in the Slate formation at Lunenburg linear markings of

* Note VI. † Murray's Reports and Map.

the nature of those which in Sweden have been named *Eophyton*,* and have been described as land plants. They are, however, of very doubtful origin, and in my judgment more akin to those trails of aquatic animals which I have named *Rhabdichnites*. This conclusion I arrived at after a careful examination of a very complete suite of Swedish specimens in London in 1870. Still, these markings are very characteristic of certain Cambrian beds. They are, for example, abundant on the surfaces of the slates of the Acadian group at St John. Professor Hind has also discovered in the quartzites of this group certain nodular bodies and markings which Mr Billings referred with doubt to the genus *Eospangia* and to casts of *Orthis*. The latter I have not seen, but Professor Hind has very kindly guided me to a bed near the Waverley Gold Mine, on the surface of which there are great numbers of the former fossils. As appearing on the weathered surface of the rock, they consist of little oval depressions surrounded by a raised ridge from which radiate a number of raised lines sometimes bifurcating. These lines appear to represent radiating plates or lamellæ rather than rods. They are of various sizes, from an inch to six or seven inches in diameter, only the larger ones having the rays well developed. They present no structure or evidence of organic matter, except that the centre has a brownish colour, as if from the oxidation of iron, and that in some specimens, differently preserved from the others, the rays also show a rusty colour. The most natural interpretation of these forms would seem to be that they consist of a central axis or central cavity surrounded with vertical radiating plates, sometimes splitting into two toward the circumference. The central axis seems to have been the original structure to which the radiating plates were afterwards added. Some specimens seem to indicate that the larger specimens were ultimately broken down into irregular groups of plates and separate plates. The material would seem to have been organic, and probably very perishable. These objects are no doubt those which Billings referred with doubt to his genus *Eospongia*; but they have no structures warranting such a reference, though they might well be compared with the problematical object from the Eophyton sandstone of Sweden described by Linnarson under the name *Astylospongia radiata*. To me they appear to be fucoids with radiating fronds, allied in form at least to Hall's *Phytopsis* from the Bird's-eye Limestone, or to Linnarson's *Scotolithus* from the Eophyton sandstone. Similar objects are abundant on the surfaces of the sandstones of the Quebec group at Metis, and they are there associated with a spiral Arenicolites allied

* Report of Geological Survey, 1870.

to *A. spiralis* of Torell, but distinct specifically, and with forms allied to *Eophyton*. In any case they may be regarded as forms of Cambrian and Lower Silurian type. In the meantime, that we may have some name wherewith to designate them, I would propose to call them *Astropolithon*,* and the Waverley species, in honour of its discoverer, *A. Hindii*.

The only other fossils known to me are specimens resembling the tubes or perforations known as *Scolithus*, and very characteristic of the Potsdam sandstone in Canada. These I found near the mouth of St Mary's River in loose blocks, which must have been derived from a neighbouring ledge of quartzite. In so far as the above fossils give any indication of age, they serve to confirm the supposition that the Gold series of the Atlantic coast is to be referred to the Cambrian period. Within that period its fossils have strong points of alliance with those of the beds known as Fucoidal sandstone and Eophyton sandstone in Sweden, and which underlie the equivalents of our Acadian series. They may, therefore, be regarded as probable equivalents of the Lower Cambrian or Longmynd series of Europe.

Professor Hind has given a good description of the characters and structure of the more important parts of the Gold series in his Reports to the Department of Mines in Nova Scotia.† He states the entire thickness of the series at 12,000 feet. Of this the Lower or Quartzite and Slate division, which includes in its middle and upper part the productive gold veins, comprises about 9000 feet, and the Upper or Ferruginous Slate division 3000 feet. The whole is thrown into a series of somewhat sharp anticlinals, which, as might be expected, are much faulted. The steepest sides of the anticlinals are usually to the north, though in some cases, as at Sherbrooke, to the south. The courses of these anticlinals are approximately east and west. The gold has been found to be most accessible in the sides and near the summits of the anticlinals, while in the synclinals the upper unproductive slates usually appear. It is also to be observed that the productive gold veins are best developed in the vicinity of the great masses of eruptive granite which traverse this formation, and in connection with which it has locally been much metamorphosed.

The gold veins, as stated in Acadian Geology, run for the most part parallel to the bedding, but cross courses and branches traversing

* Star-like stone.

† Report on Waverley District, 1869; Sherbrooke, 1870; Mount Uniacke, Oldham and Renfrew, 1872.

the beds are very frequent,* and there is no proof that these ar ancient than the conformable veins or "leads." Though occu in the Quartzite division, the auriferous veins usually follow ban slaty rock included in the quartzite, a circumstance which favours their profitable working.

In my Acadian Geology, I associated with the Atlantic series the extensive deposits of mica slate and micaceous g found in the peninsula ending in Cape Causo, and also very ex sively in the west, more especially in Shelburne County. I regarded all the true granite of this district as intrusive, and the evidence of the fossiliferous rocks cut by it on the Nictaux Ri as of later date than the Oriskany period. It has, however, la been customary to regard much of the granite as gneiss, and speak of this and the associated schistose rocks as Laurentian Huronian. Aware that many new exposures had been made recent years by mining and roadmaking, and being desirous satisfy myself as to whether any change was required, I revis the district around Sherbrooke and the St Mary's River, and so fortunate as to find what seems to me conclusive evidence of correctness of my former views.

Eastward of Sherbrooke, the beds of the Gold series run end against the great mass of granite rock extending from near the Mary's River beyond Indian Harbour, and given in my Aca Geology as a typical illustration of intrusive granite.† At a p near the Upper Indian Harbour Lake I found the granite quartzite in contact, the line of junction running about south- and the quartzite dipping north-east at an angle of 70°. At junction the quartzite is slightly changed in character, ha apparently minute hornblende and mica crystals developed in it; the granite sends numerous veins into the quartzite, and in t becomes coarser in texture, and presents beautiful aggregation plumose mica. This is, I believe, the character of the junc everywhere, except that where the slaty bands approach the gra they are more altered than the quartzite. (See Frontispiece.)

At Cochrane's Hill, near the forks of the St Mary's River, a gold mine has been opened on quartz veins said to be rich visible gold than usual, and included in beds which must belo the upper part of the Quartzite series. These beds lie, howeve the line of the great intrusive granite belt extending from Canso along the south side of Chedabucto Bay, and they are

* I have observed and sketched examples of this at Uniacke and Sherbrooke

† Page 619, and plate, p. 613.

trated by numerous granite veins, which in the vicinity of the mine were seen to vary from six feet to less than an inch in thickness. In these circumstances, the gold-bearing slates and quartzites have experienced a metamorphosis equal to any observed elsewhere in this coastal series. The slates have become perfectly crystalline. Mica-schists, or micaceous gneisses, with crystals of chiastolite and staurolite, have been developed in them, and they are absolutely undistinguishable from the rocks of the Cape Canseau peninsula and of Shelburne and Barrington, as described in Acadian Geology. This I consider a perfectly conclusive vindication of the views held by me in 1868, and I have reason to believe that it will apply to all other localities. I would not, however, maintain the negative conclusion that nowhere in this district do Laurentian or Huronian rocks penetrate the Gold series; though the only locality where I have seen any rocks which appeared likely to be of this kind, is in the extreme west, in the vicinity of Yarmouth, where certain epidotic, felspathic, and chloritic rocks appear, of a very different character from those of other parts of the coast, and which may be Huronian (Ac. Geol., pp. 616, 620). Mr Selwyn has recently examined these rocks more in detail than I have been able to do, and regards them as probably older than the Gold series.*

The apparent relation of the granite veins and auriferous quartz at Cochrane's Hill suggests an interesting question with respect to the age of the latter. It would seem that the quartz veins cut or disturb those of granite, and hence are newer. Now, if the intrusive granite is of Upper Silurian or Devonian age, this would limit the age of the gold veins on one side, just as the occurrence of drift gold in the Lower Carboniferous conglomerate of Gay's River limits it on the other. In this case the movements of the Cambrian rocks which opened up the gold veins must have taken place in the Devonian age.† There is, however, some reason to believe that all the gold veins are not precisely of one date, and this conclusion may apply only to the later of them.‡ Perhaps, taking this in connection with the fact already stated, that the gold deposits seem richer in the vicinity of the granite, we may be justified in affirming that the granite intrusions and gold veins are "roughly contemporaneous." This is the conclusion at which I arrived in 1868, and stated in the second edition of Acadian Geology.§

Mr Selwyn has ascertained that the granite and gneissose rocks of

* Report, Geol. Survey, 1870.

† Acadian Geology, p. 631.

‡ Mr Poole mentions to me a case of granite apparently "capping" a quartz vein.

§ See Acad. Geol., pp. 665, 666.

the south coast in Shelburne, are probably continuous i
those of Annapolis, and thus occupy a much greater are
represented in my map.*

I am indebted to Henry S. Poole, Esq., Inspector of
Nova Scotia, for some notes on the distribution of granit
the Gold series of the eastern coast. He informs me th
crosses the Post road from Musquodoboit, five miles
junction of Pictou, Halifax and Guysboro' counties. It a
at Liscomb Lakes, south of the west branch of St Mary's R
in the hills west of Mooseland, between Mooseland and t
It appears to extend from Mooseland to the north-eastern
Ship Harbour, and also occurs at Sheet Harbour. Mr Pool
with me in regarding the granites as intrusive, and ment
tongues or veins extending into the gneiss, the fragments of
quartzite caught up in the granite, and the development of ch
in the vicinity of the granite masses, as corroboration of this.

It may be well to explain here that in designating the gr
igneous and intrusive, I by no means wish to declare myself
those theories of its origin which would regard it as cons
indigenous rock fused by aqueo-igneous agency in place, or
so. I have referred to this question in Acadian Geolo
500, 501, and my views regarding it still remain the same.

I may further remark that, independently of the stratified c
of gneiss, Plutonic granite has always, in so far as my ex
extends, a different texture, quite manifest to an experienced
dependent, I believe, chiefly on the more regular forms and
density of the crystals of felspar in granite as compared with

Mr Fletcher, of the Geological Survey, has discovered, in
beds near St Andrew's Channel, Cape Breton, fossils which
belong to the Cambrian series, and are apparently new
the Acadian or Menevian group. They consist, accordin
Billings, of an *Obolella*, *Orthisina*, and *Dictyonema*, and a
of Primordial type; and the beds holding the *Lingula* or
are very like the Lingula shales of St John. The series i
terized as consisting of a purple, red, and green slate, s
and limestones, with beds of felsite.† It thus differs in
from the Acadian group, as developed at St John, and also
Cambrian of the Atlantic coast of Nova Scotia. It res
crystalline rocks of the Boisdale Hills, referred to under
which must thus be Lower Cambrian or Huronian.

* Report of 1870.

† Report, Geological Survey, 1875–76.

Mr Fletcher has still more recently (1877) procured fossils, not yet described, from the vicinity of Miré River, where beds similar to those of St Andrew's Channel are extensively developed, and which include an *Agnostus* and other trilobites of primordial type, but specifically distinct from those of the Acadian group; and also a small Orthis, apparently allied to *O. Evadne*, Billings, from the Quebec group, or to *O. lenticularis*, Dalman, of the British Upper Lingula flags. These fossils I regard as indicating a position probably Cambrian, but later than that of the Acadian beds of St John. The beds containing these fossils are associated with the volcanic ash series of Southern Cape Breton, but I have no information as yet with reference to their precise geological relations. It is interesting and instructive thus to find the Upper Cambrian series appearing in Cape Breton. With the Acadian or Menevian, and the probable Longmynd series of the coast of Nova Scotia, it serves to complete the representation of that system of formations in Acadia. I may add that Professor Bailey informs me that in the belt of old rocks, north of the central Coal-field in New Brunswick, there are portions, apparently older than the Silurian rocks of that region, and resembling the Nova Scotia coast series, like which they are auriferous.

12. THE HURONIAN.

The Coldbrook series of Messrs Bailey and Matthew, rising from beneath the Cambrian fossiliferous slates, was referred to this age in my second edition; and this view has been still further confirmed and extended by recent observations of Professor Bailey. From these it appears that the Coldbrook or Huronian series rests unconformably on the Laurentian, and that pebbles of the latter are included in its conglomerates. On the other hand, the Acadian or Menevian beds lie unconformably on the Coldbrook series. Further, the Upper Huronian is now identified with the "coastal series" of former reports, and thus greatly extended, more especially to the eastward of St John. There would also appear to be indications of unconformity between the upper and lower members of the Huronian itself. It thus appears as a distinct formation, or group of formations, between the Laurentian and Acadian groups, and connected with neither. The study of a series of typical specimens, kindly furnished by Mr Matthew of St John and Mr Murray, director of the Geological Survey of Newfoundland, enables me to affirm a remarkable similarity in mineral character between the rocks described as Huronian in these two regions, while their relations to the Laurentian below and Menevian above are the

same. The peculiar fossils, however, *Aspidella* and *Arenicolites*, ε to *A. spiralis*, discovered by Murray in the Upper Huronian of l foundland and described by Billings, have not yet been recognis New Brunswick.

The Coldbrook series is remarkable for the abundance in felsites, felsitic breccias, porphyry, diorite, and other crystallin cryptocrystalline rocks, which, though stratified, are evidently volcanic origin, and if such rocks are to be considered as everywh of this age, the classification of the older rocks of Acadia would greatly simplified. It is evident, however, that we must sepa the Mascarene series, and other rocks of this character, with Up Silurian fossils; and there is no good evidence that the Cobeq series and its equivalents in Pictou and elsewhere are older than t Lower Silurian. There seems, however, good reason to class Huronian, or at least as Lower Cambrian, the rocks of the Boisd Hills in Cape Breton, which Mr Fletcher finds to underlie the fossi ferous Cambrian of that region, and which are more quartzose a micaceous than the rocks of the Cobequid series. It is not impossil that rocks of this age may also occur in the vicinity of the Cambri beds found at Miré. We may also conjecturally class as Huroni the chloritic rocks of Yarmouth.

I may repeat here my conviction, founded on the comparison large suites of specimens from Newfoundland, and from Nova Sco and New Brunswick, as well as from the typical localities in La Huron, that volcanic and trap-ash rocks of various composition w in process of deposition from the Huronian to the Upper Siluri inclusive, and that they cannot be distinguished in hand specime It is only by considerations based on stratigraphy and fossils tl these rocks can be ultimately classified with certainty. Unfortunate in many cases, decisive evidence of these kinds is not easily obtain and in the meantime our classification has to remain to a great ext conjectural.

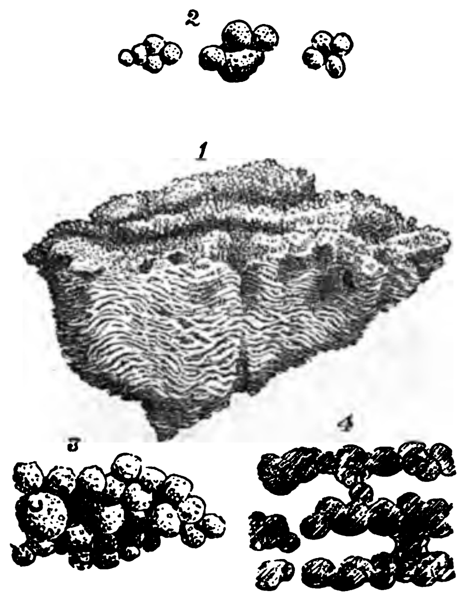
13. THE LAURENTIAN.

These rocks, as they occur near St John, New Brunswick, h been arranged by Messrs Bailey and Matthew, in their re Reports, in a Lower and Upper series.* The former consists ascending order, of gray gneiss, red and gray gneiss, and dark-g gneiss, with chloritic gneiss and diorite. The latter consist limestone, with graphite and serpentine, gray quartzites and dio gray slates and limestones with diorite. In one of the Upper L

* Geol. Reports, 1871, etc. See also Note VI.

stones I have recognised somewhat obscure structures, which appear to indicate the presence of fragments of Eozoon.* In consequence of this discovery, I reprint here some illustrations of the structure of the typical Canadian Eozoon, as guides to observers searching for them in the Laurentian of the Lower Provinces (Figs. 16 and 17). Full descriptions and other details will be found in my work, "Life's Dawn on Earth." †

Fig. 16.—*Eozoon Canadense.*



(1) Weathered specimen, natural size.
(2) Casts of Acervuline chambers.
(3) Surface of a flat chamber.
(4) Section showing casts of flat chambers.

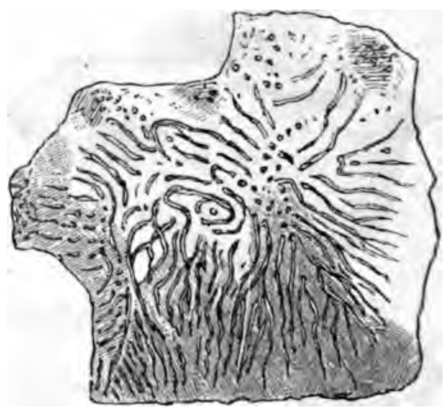
Dr Hunt seems, in recent publications, inclined to doubt the Laurentian age of the upper part of these rocks, and to refer them, with the Hastings group of Ontario, to a somewhat later though pre-Cambrian age.

Dr Honeyman and Professor Hind have suggested the Laurentian age of certain rocks at Arisaig, in the Cobequids, and associated with the coast Metamorphic series, but I do not regard the evidence of this, either from fossils, mineral character, or superposition, as conclusive, andmust refer for it to the memoirs of these gentlemen in the Trans-

* Proceedings, American Association, 1876. † London, 1875.

actions of the Nova Scotia Institute, and the Journal of the Geologi Society of London. I must, in like manner, decline to receive as Laurentian age the felsitic and other rocks of Cape Breton, referr to this system by Mr Fletcher in the latest Report of the Geologic Survey. I would except those of St Anne's Mountain, the lith logical resemblance of which to the Lower Laurentian of Canada indisputable, and the evidence that they may be of this age h certainly been much strengthened by the recent observations of M Fletcher.* Specimens, and the observations of Mr Brown and M Campbell and others, induce me also to believe that in the little islan of St Paul's, and in some parts of Northern Cape Breton, we may hav

Fig. 17.—*Canal System of Eozoon—Magnified.*



a continuation of the rocks referred by Mr Murray to the Laurenti in Newfoundland. With these exceptions, I have not seen in Nov Scotia, unless in travelled boulders, any rock that I could believe t be lithologically equivalent to the Laurentian of Canada, nor have found any stratigraphical evidence of the occurrence of such rocks.

14. COMPARISONS WITH OTHER COUNTRIES.

The new facts above stated in relation to the older formation somewhat modify the statements made in Acadian Geology as to th

* I observe, in some recent papers on this subject, the statement that I had be these old rocks of Cape Breton to be intrusive syenites newer than the Carbonifero age. On the contrary, I have held that the Metamorphic region of northern Ca Breton formed "a rocky island in the seas of the Carboniferous period." The o foundation known to me for this statement is my reference of the somewhat alte limestones of Low Point, in Eastern Cape Breton, to the Lower Carboniferous. believe that later investigations would indicate that they are older.

geological history of the region now included in the maritime provinces. They establish what I could then only indicate as probable, that the great igneous outbursts of the Devonian age, accompanied with profound alteration of the older sediments, with much disturbance of these beds, and the introduction into them of mineral veins, were preceded by a long series of emissions of trachytic lavas and volcanic ashes and breccias, now represented by the felsites, porphyries, and agglomerates of the Huronian, Cobequid, and Mascarene series. Beginning with the Huronian age, these eruptive actions were interrupted in the Cambrian, but recurred with great intensity in the Lower Silurian, and extended into the Upper Silurian age. For this reason, the rocks of these periods in the Acadian area present a marked lithological contrast to those which were accumulating at the same time in the great quiet sea areas of the interior of the continent, and it becomes extremely difficult to correlate these deposits in detail. The peculiar characters of the Quebec group of Eastern Canada, and of the rocks called Taconic by Emmons further south, are no doubt connected with the great igneous actions of the Lower Silurian age. We may ultimately find that in the Silurian period the Atlantic coast of America was the theatre of igneous activity comparable with that which has prevailed in later periods on the Pacific coast, and that the relations of the coastal and interior rocks are similar to those between the Mesozoic porphyrites and trachytes of British Columbia, and the contemporaneous shales, marls, and sandstones of the interior plains.*

It is to be observed here that the character of the older deposits in the Acadian area has been modified not only by contemporaneous igneous action, but by the action of the Arctic currents in drifting along the Atlantic border earthy matter set free by frost and aqueous denudation in the north; as well as by the metamorphic influence connected with the subsequent igneous ejections of the Devonian.

It is further to be observed, that the peculiar features above referred to ally the rock formations of the Silurian age in Nova Scotia and New Brunswick with those of Great Britain, in which also there are great series of bedded volcanic rocks and ash rocks both in Cumberland and Wales. A rough equivalency may, indeed, now be traced in these rocks on the two sides of the Atlantic, as represented in the following table:—

* See on this subject a paper by Mr G. M. Dawson, On Mesozoic Volcanic Rocks of British Columbia, Geological Magazine, July 1877.

COMPARATIVE TABLE.

ENGLAND, ETC.	NOVA SCOTIA AND NEW BRUNSWICK.
Upper Silurian.	
Ludlow, Wenlock, and Llandovery or Mayhill.	Upper Arisaig Series, Mascarene Series; Lower Arisaig, New Canaan, Wentworth, and Restigouche Series.
Lower Silurian.	
Caradoc and Bala, with Snowdon Felsites and Ash Beds, Coniston and Knock Series.	Upper Cobequid Series, Slates, Felsites, Quartzites, and Greenstones.
Great Felsite and Trap Ash Series of Borrowdale (Ward).	Lower Cobequid Series, Felsites, Porphyrites, Agglomerates, and massive Syenite of Cobequids, Picton, and Cape Breton.
Lower Llandeilo Flags and Shales, Arenig Series, Skiddaw Slates, etc.	Graptolitic or Levis Series of Quebec and North New Brunswick, part of Cape Breton Series?
Cambrian.	
Tremadoc Slates and Lingula Flags.	Miré and St Andrew's Channel Series in Cape Breton.
Menevian Series.	Acadian Series of St John, New Brunswick.
Longmynd Series, Harlech Grits, and Llanberis Slates.	Quartzite and Slate of Atlantic Coast of Nova Scotia.
Huronian.	
Pebidian and Dimetian Series (Hicks), containing Felsite, Chlorite Schist, and Serpentine.	Huronian Felsites, Chloritic and Epidotic Rocks of St John, Yarmouth, and of Cape Breton in part.
Laurentian.	
Older Gneisses of Scotland and of Scandinavia.	Gneiss, Quartzite, and Limestone of St John, Portland Group, Gneiss of St Anne's Mountain?

This table may at least serve to suggest comparisons, even though some of its correlations should be shown, by further examination, to require correction. In any case, the facts exhibited illustrate the general truth, now well established, that throughout geological time, the formations on the borders of the great oceans have been different in character from those of the continental plateaus and from those of the abyssses of the sea.

15. MINERAL RESOURCES.

Coal, &c.—The Report of the Inspector of Mines for Nova Scotia for 1876, shows 24 collieries in operation. Their total produce was 709,646 tons, but this is far below their present capacity, the trade

being in a very depressed condition. All these mines are in the Cumberland, Pictou, and Cape Breton Coal areas. In New Brunswick, according to the report on the exhibits at the Centennial Exhibition, the only coal-mine in operation was that at Grand Lake, Queen's Co., the annual production being only 3000 chaldrons. Beside this, there is the remarkable Albertite of the Albert Mines, Albert County, a vein of altered bitumen in the Lower Carboniferous rather than a Coal deposit. This yielded in 1874, the latest report I have seen, 7000 tons. A new mining enterprise (the Beliveau mine) has recently been commenced near the Petitcodiac River, in search of this valuable mineral.

There are, in the Carboniferous of New Brunswick and also of Nova Scotia, immense deposits of pyroschist or bituminous shale, capable of yielding as much as 63 gallons of oil, or 7500 feet of illuminating gas, per ton. Owing to the great cheapness of petroleum, little attention has been paid to these shales for some years, but it is likely that they will before long again be in demand.

The Coal areas now worked in Nova Scotia and New Brunswick are undoubtedly those most accessible and promising, and the question of working those beds of less thickness, or less accessible, or those concealed under the beds of the newer Coal formation, is not likely to be raised for some time. That large available areas of these kinds exist there can be no doubt; but should present commercial relations with the United States continue, the first great stimulus to the coal industry must arise from the development of the iron ores, so abundant in the vicinity of the principal Coal-fields.

Devonian Anthracite.—At Point Lepreau in New Brunswick, a remarkable discovery has been made of anthracite in a horizon referred by Mr Matthew to the upper part of the Dadoxylon sandstone. I am informed by Mr Matthew that it occurs in a vertical bed from 6 to 10 feet in thickness, in olive-coloured sandy shales. It is of a granular texture, and may be regarded as an anthracite, as it contains only about 5 per cent. of volatile matter. A specimen analysed by Dr Harrington gave 35·8 per cent. of ashes; but possibly this may not represent the general quality of the deposit. Whether of economical value or not, it is of interest as the only example of Devonian coal in North America, except the little bed, 2 inches thick, occurring in the Gaspé sandstone.*

Iron.—The only extensive works at present in operation in Nova Scotia are those of the Steel Company of Canada at Londonderry—formerly the Acadia Company. These works depend on the great veins of iron ore on the south side of the Cobequid Mountains (Ac.

* Report on Fossil Plants of Devonian, pp. 7, 8.

Geol., p. 582). The supplies of ore are at present almost entirely derived from extensive veins of limonite, constituting part of the great vein of specular and spathic ore which was first worked at this place, but is now neglected, owing to the greater cheapness and more ready reduction of the limonite; 15,274 tons of ore were mined in 1876.

In a recent visit to this mine, I was pleased to see an admirable smelting establishment with two blast furnaces of the most improved construction, and a beautiful village, where, in my former visits, had been a wild forest ravine. I found that the extensive adits now worked at Martin's Brook are in the same veins which I originally described, and that the change in the chemical quality of the ore depends on the fact that the mine has penetrated into portions of the vein where the ankerite and carbonate of iron have been decomposed and oxidized by water, owing to the more open and permeable character of the containing rock.

The iron deposits in the Silurian rocks on the East River of Pictou, and their associated deposits, have recently attracted some attention; but no smelting operations have yet been undertaken. The ores here consist of—(1.) A bed of red hematite in the lower Helderberg slates. It has a percentage of 43 to 54 of iron, and varies in thickness from 10 to 30 feet. Its outcrop has been traced for several miles over ground where it is very accessible, and not more than 12 miles distant from the great Pictou collieries. (2.) A vein of crystalline specular ore, whose geological relations are similar to those of the Londonderry vein. It has been traced for a mile or more, and in some places has a thickness of 20 feet of pure ore. Masses of magnetite occur in parts of the vein, and also quantities of spathic iron and ankerite. (3.) Veins of limonite, which occur in many places on the East River of Pictou; some of them are of large dimensions, and associated with subordinate veins and concretions of pyrolusite or manganese ore. (4.) In the Lower Carboniferous, on Sutherland's River, there is a remarkable vein of crystalline spathic iron ore or carbonate of iron, which will no doubt eventually be worked in connection with the other deposits.

In Cape Breton, extensive discoveries of hematite are reported on the East Bay of the Bras d'Or, and in other localities not distant from the collieries of the east part of that island. Valuable deposits of limonite are reported at Brookfield and Old Barns, in Colchester County, and further discoveries of magnetic ore have been made in the bed of iron ores associated with the Oriskany formation at Nictaux and Moose River.

Beds of clay ironstone, which occur in the Carboniferous of Nova Scotia, have naturally attracted little attention in the presence of those

great deposits of rich crystalline ores lying unused in the immediate vicinity of the Coal-fields. The latest discovery of this kind is on the French River, Pictou County, where beds of nodular clay ironstone from 6 inches to 4 feet thick are reported, the ore containing 35 per cent. of iron.

In New Brunswick the beds of red hematite occurring at Jacksontown, near Woodstock, in beds believed to be of Upper Silurian age, are not now worked, though formerly successfully mined and smelted. These beds are numerous, and from 6 inches to 8 feet thick. Their geological characters seem to resemble those of the great Pictou hematite already referred to. Bog iron ores, believed to be of commercial value, are found at Burton, Sunbury County, and at Maryland, York County.

Iron ochres, used as "mineral paints," abound in connexion with the deposits of iron ore as stated in Acadian Geology, and have been worked on a limited scale at various points, as has also the umber of Chester.

Copper.—Though many indications of copper have been observed, it is only recently that veins of workable dimensions have been found in Nova Scotia. A locality at Polson's Lake (Ac. Geol., p. 692), which has attracted some attention for many years, has at length revealed an apparently continuous vein of spathic iron holding rich copper pyrites. A neighbouring area near the Lochaber Lake exhibits several apparently rich veins, said to be 2 to 6 feet in width. There can be little doubt that the former place will soon become the seat of an important mining industry. The ores occur in a slate formation associated with quartzite, and which I believe to be equivalent to the Cobequid series.

Attempts have recently been made to work the native copper in the Triassic trap of Cape D'Or, and the nodules of gray copper in the Carboniferous sandstones of New Annan, but with little success.

In New Brunswick, ores of copper in veins, and disseminated through slaty rocks, have been found in several places of the south coast, in rocks of very similar character with those holding the Nova Scotian ores above mentioned. The attempts to open them profitably have hitherto been unsuccessful. Vitreous copper ore is also found in connexion with the Triassic trap of Grand Manan, but I have no definite information as to its economic importance.

Manganese.—The peroxide of manganese, or Pyrolusite, occurring in veins and "pockets" in the Lower Carboniferous limestone is worked profitably at Markhamville, New Brunswick, and at Teny Cape in Nova Scotia, where it occurs under similar conditions. This

mineral has also been found in profitable quantity on Onslow Mountain, in Colchester County. It is associated with limonite on the East River of Pictou, and its occurrence has been reported in several other places, though in uncertain quantity.

Lead.—A vein of galena has been worked on in Caledonia, Guysboro', though as yet the results are uncertain. A vein of argentiferous galena, yielding 135 lbs. lead and 2·95 ounces of silver to the ton, is also reported on the North River of St Ann's Bay, Cape Breton. This vein is stated to be five inches in thickness. The deposit of galena in Lower Carboniferous limestone at Gay's River (Ac. Geol., 275) has also attracted some attention, but I believe has not been worked on a large scale as yet.

Antimony. — Stibnite, or antimony glance, occurs in veins in a gangue of quartz, in rocks believed to be of Upper Silurian age, at Prince William, York County, New Brunswick. The ore is mined and smelted with profit, and is also made into the alloy named "Babbit Metal."

Gold.—In Nova Scotia thirteen gold districts are reported as being worked in 1876. The total yield was 12,038 ounces, nearly half of this being from the Sherbrooke district, and the next most important being those of Oldham, Waverley, and Wine Harbour. All the gold mines at present worked are in the Cambrian Quartzite formation of the Atlantic coast, with one remarkable exception. This is the Carboniferous conglomerate of Gay's River, referred to in Acadian Geology (p. 277) as an instance of a gold alluvium of Lower Carboniferous age, and as a proof that the gold veins are of older date than the Carboniferous. It is stated in the report of the inspector that in one area the conglomerate was worked along a run or depression of the slates for 500 feet.

The gold is obtained by breaking up the conglomerate and panning the debris; and, as in most modern gold gravels, the richest part of the deposit seems to be near the bed rock. 246 ounces were obtained from this deposit in 1876. Professor Hind states* that a similar instance of the occurrence of gold in a Carboniferous conglomerate occurs in the peninsula opposite Baddock in Cape Breton. Here, however, it is near the summit of a thick conglomerate, implying peculiar circumstances in its deposition.

The gold-mining industry is believed at present to be in a healthy state, though reduced in amount from the times of early excitement; and it is likely gradually to extend.

Silver.—The sulphide of this metal, and also argentiferous galena,

* Paper on Gold-Mining, Society of Arts, May 1870.

occur in a vein in Metamorphic rocks at Watchabuckt in Northern Cape Breton, and the occurrence of drift fragments of these ores in the streams in that district indicate that there must be other deposits in this, as yet, little explored region.

Freestone and Grindstone.—The export of these materials from Nova Scotia and New Brunswick still continues to be large. The celebrated Lower Cove quarries at the Joggins, alone, exported in 1876 grindstones and whetstones to the value of 35,847 dollars. Large and prosperous quarries of a stone, quite equal to that of the Joggins, exist at New Bandon, or Clifton, Gloucester Co., New Brunswick. Considerable quarries of building-stone are also in operation at Wallace and Pictou, Nova Scotia; at Dorchester and Hopewell, New Brunswick, and many other places.

Other Building and Ornamental Stones.—The cutting and polishing of red syenite and granite are carried on at St George, Charlotte County, New Brunswick. The stone produced is equally beautiful with the red granite of Scotland. Marble of varied hues, and favourably situated for quarrying, has been discovered at Marble Mountain, on the Bras D'Or Lake, Cape Breton.

Gypsum.—This mineral is still extensively exported from Nova Scotia and New Brunswick. The exports from Nova Scotia in 1876 are stated at 80,920 tons, and no less than 129,000 tons are stated to have been quarried at Hillsboro', New Brunswick, in 1875. A large portion of this was ground and calcined at the quarries.

According to Dr How, anhydrite or anhydrous gypsum is worked at Cheverie, Hants County, and exported for agricultural purposes. It is, of course, harder to grind than common gypsum, and cannot be used for moulding or plastering, but for land it may be regarded as more valuable than the hydrous variety, as wanting the water, which amounts to about 20 per cent. of the weight of the latter.

Barytes.—The sulphate of barium or heavy spar is mined in small quantity at Five Islands (Ac. Geol., 592), and is known to occur at many other places.

Dr How, in his Report on the Mineralogy of Nova Scotia,* also directs attention to the numerous *Brine Springs* issuing from the Lower Carboniferous rocks, and the working of which has been attempted on a large scale at Antigonish. He also notices important discoveries of *Iron Pyrite* or sulphur ore; and mentions *Titaniferous Iron Ore* as occurring at Sable River, Shelburne County, and in sand at Digby Cove. This Report, as well as that of the Geo-

* Halifax, 1868.

logical Survey of Canada, those of the Inspector of Mines of N Scotia, those of Professor Hind on the Gold Fields, and those mad behalf of private mining corporations, contain a large amour detail respecting the resources and mining industries of the Aca Provinces, which it is impossible to summarize here. The above r are intended merely to supplement the more extended notices g in Acadian Geology.

The great coal and iron industries of the Acadian Provinces, with these indirectly all other mineral industries, are at pr much depressed, not only by the general depression of trade in t minerals, but also by those artificial restrictions and arrangem which shut out their produce from the largest American ma while they give no preference or protection at home. It is credi to the intelligence and industry of these Provinces, and at the time an indication of their great mineral wealth, that under circumstances they have been able to do so much as appears the Report of the Inspector of Mines for 1876.

NOTES AND ADDENDA.

1. *Lignite from the Trias of New Brunswick.*

Jackson and Alger, in their memoir on Nova Scotia Geology, mentioned the occurrence of lignite at Cape Blomidon in the Triassic sandstones, but I have not succeeded in discovering it. Last summer Mr Ells, of the Geological Survey, obtained a specimen in the sandstones of the opposite side of the Bay of Fundy at Martin's Head. This specimen proves to be a coniferous wood with one row of large disks in the cells, and of the same type with silicified wood found at Quaco, and referred to in Acadian Geology, p. 108. It is also of the same type with *Dadoxylon Edwardianum*, referred to above as characteristic of the Trias of Prince Edward Island, and is similar to fossil wood which I have received from the Mesozoic of Virginia.

2. *Lower Carboniferous Fishes of New Brunswick.*

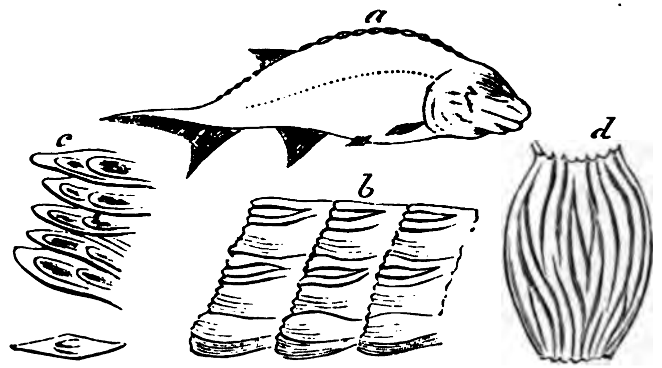
The recent sinking of a shaft on the property of the Beliveau Albertite and Oil Company on the Petitcodiac River, has exposed a new and interesting deposit of fossil fishes in the rich bituminous shales of that district, which contain the remarkable deposits of Albertite, described in Acadian Geology, p. 231 *et seq.* The bed affording these fossils is a dark-brown bituminous shale, and, I am informed by Mr E. B. Chandler, to whom I am indebted for an interesting collection of the fish remains, is from four to five feet thick. The specimens thus presented, with those previously in my collection and one kindly given to me by Mr F. Adams of this University, and the valuable memoirs recently published by Dr Newberry in the Ohio Report and by Dr Traquair in the Journal of the Geological Society, enable me now to give a revision of the fishes of this locality, as described by Dr Jackson in his Report of 1851 on the Albert mine, which I was unable to do in my second edition, owing to the small number of specimens at my disposal.

In the collections in my possession I recognise, in all, five species three of them very small, and two of larger size. Of these, one, which is unusually well preserved, and is the smallest of the whole, appears to be new, and I shall begin by describing it.

Palæoniscus (*Rhadinichthys*) *modulus*, S.N.—Length, five to six centimetres; greatest breadth, 15 to 17 millimetres—the proportion of length to breadth being about five to one and a half. Head, oval and obtuse; details not preserved, except that the bones are sculptured with fine waving lines. Body gracefully curved, and upper lobe of tail long and slender. Pectoral fins small, with stout, unjointed rays. Ventral not distinctly preserved, but apparently small and nearer to pectorals than to anal. Dorsal and anal of moderate size and opposite each other. Caudal very heterocercal, with the lower lobe sharply pointed. Fins with well-developed fulcral spines especially large at the base of the caudal. Scales

of the sides rhombic, coarsely toothed on the posterior edges, and el ately sculptured with flat, scaly ridges, corresponding to the teeth o edge. The ridges are arranged in an upper and lower series, the l oblique to the former, so that each scale has the appearance of being posed of two distinct portions. Lower surface of scales smooth, wi few furrows corresponding to the ridges above, and the posterior e apparently serrate. Caudal scales narrowly rhombic, pointed, and wi few central lines. The back is protected with about ten large oval s between the head and the dorsal. They are sculptured with waving l curving with the edges, and are apparently truncate and serrate bel The fish figured by Jackson, Pl. II., Fig. 5, but not named, probably bel to the above species.

Fig. 18.—*Palæoniscus modulus*, s.n.



(*a*) Outline, natural size.
(*b*) Series of Scales enlarged, seen from inside. The lower row are those on mesial line.
(*c*) Surface of exposed part of scale from side and from upper lobe of tail, showing sculpture, enlarged.
(*d*) One of the dorsal scales, enlarged.

This beautiful and elaborately ornamented little fish is a perfect mod in miniature of that type of lower Carboniferous Palæoniscids to which belongs, and which has recently been separated by Dr Traquair in tl genus or subgenus *Rhadinichthys*. For this reason I have given it tl specific name *modulus*. To the same genus belong the two next specie described by Jackson, of which I shall give merely distinctive marks.

P. Alberti, Jackson, is larger than the preceding. The scales have mo numerous striæ. The dorsal scales are rounded posteriorly. The posteri edge of the anal fin approaches nearly to the caudal, and extends conside ably behind the posterior edge of the dorsal.

A specimen collected by Mr Ells, of the Geological Survey, indicates fish of the same general form with *P. Alberti*, but about 6 inches lon The details are not sufficiently preserved to show if it differs in these fro the above-named species.

P. Cairnsii, Jackson.—About the same size with the last, but mo slender, and the head less obtuse in front. Scales thick and with f

striæ, and less numerous serrations. Dorsal scales pointed posteriorly. Anal fin somewhat remote from caudal and opposite dorsal.

The next species, and perhaps the last, may belong to the genus *Elonichthys* of Giebel. They are much larger than the preceding.

P. (Elonichthys) Brownii, Jackson, is deep in form, with large dorsal and anal, the latter reaching almost to base of caudal. Scales of body broad and with numerous fine horizontal striato-punctate furrows, which turn abruptly upwards at the anterior side of each scale. A nearly perfect specimen, collected by Mr Ells, is 10 inches long and 3¼ inches wide, the breadth at the dorsal fin being about equal to that at the shoulder, andsuddenly diminishing to the tail. The crystalline lens of the eye is preserved in this specimen in calcite, and shows its structure, which is on the same plan with that of our modern ganoid *Amia ocellicauda*. It is the firstinstance known to me of the preservation of the structure of the eye of a Palæozoic fish.

P. Jacksonii, S. N.—A species figured, but not described, by Jackson, is represented by several fragments in my collection, and by a cast obtained from Mr Matthews of St John. It is the largest of these fishes, reaching a length of 15 inches. It may be distinguished from the last by its more slender form, its small anal fin, more remote from the caudal, and by the character of the scales, which are marked with numerous horizontal striæ, and have in the broader ones a few deep and strong serrations posteriorly.

The whole of these fishes have been preserved entire; their bodies being perfectly flattened, and thrown into attitudes which imply that they were embedded when living or immediately after death. The material in which they are contained is shown, by its microscopical and chemical characters, to have been a vegetable muck or mud, and the fish were either overwhelmed by it in the manner of a bursting bog, or were stifled by the non-oxygenated water mixed with this mud, and suddenly killed and embedded in the accumulating sediment. That they occur in this perfect state, and in a limited thickness of the deposit, may imply that at certain times they were overwhelmed by the irruption of the fetid organic mud into the water in which they lived. The bed is low down in the Lower Carboniferous series, being the equivalent of the Horton series of Nova Scotia; so that these fishes are among the oldest that we know in the Carboniferous system; but we know, from the Horton beds, that many far larger and predaceous ganoids were their contemporaries. No remains of these have, however, as yet been found in the Albert or Beliveau beds, which were probably deposited in limited fresh-water basins, perhaps not ordinarily accessible to the larger fishes.

Sir Philip Egerton* and Dr Traquair† have both remarked on the similarity of these fishes to those found in the Lower Carboniferous of Scotland, and Dr Newberry has described very similar species from the Carboniferous of Illinois and Ohio.‡

3. *New Spirorbis.*

Spirorbis arietina, referred to at page 35 above, is figured in the Report of the Canada Geological Survey for 1866–69, p. 14. It is spiral, sinistral;

* Journal of Geological Society, 1853.

† Report on Illinois, vol. ii.; Palæontology of Ohio, vol. i.

‡ Journal of Geological Society, 1877.

whorls four, the first three regularly spiral and not flattened for attachment, except at the apex; the last whorl diverging from the others irregularly in the manner of a *Vermetus*. Length about 3 millimetres. The surface uneven, with obscure wrinkles on the last whorl, and microscopic lines of growth on the others. Shell thin, with delicate tubular structure, much finer than that of *S. carbonarius*. I have not recognised this shell elsewhere than in the limestone of Fraser's Mountain, near New Glasgow, except in a few rare and doubtful examples at the Joggins. It was probably attached by a narrow space at the apex to submerged plants, in the manner of the modern *Spirorbis porrecta;* and, being broken from its attachment, or the vegetable matter being removed by decay, remained loose and unattached, as it appears in this limestone, some portions of which are crowded with specimens.

4. *Cone-in-Cone.*

Mr H. Poole informs me that the figure of this curious concretion, at page 676 of Acadian Geology, should be inverted; as, in the beds from which the specimens were obtained, the conical ends of the concretions were below and the flat sides above.

5. *Diabase.*

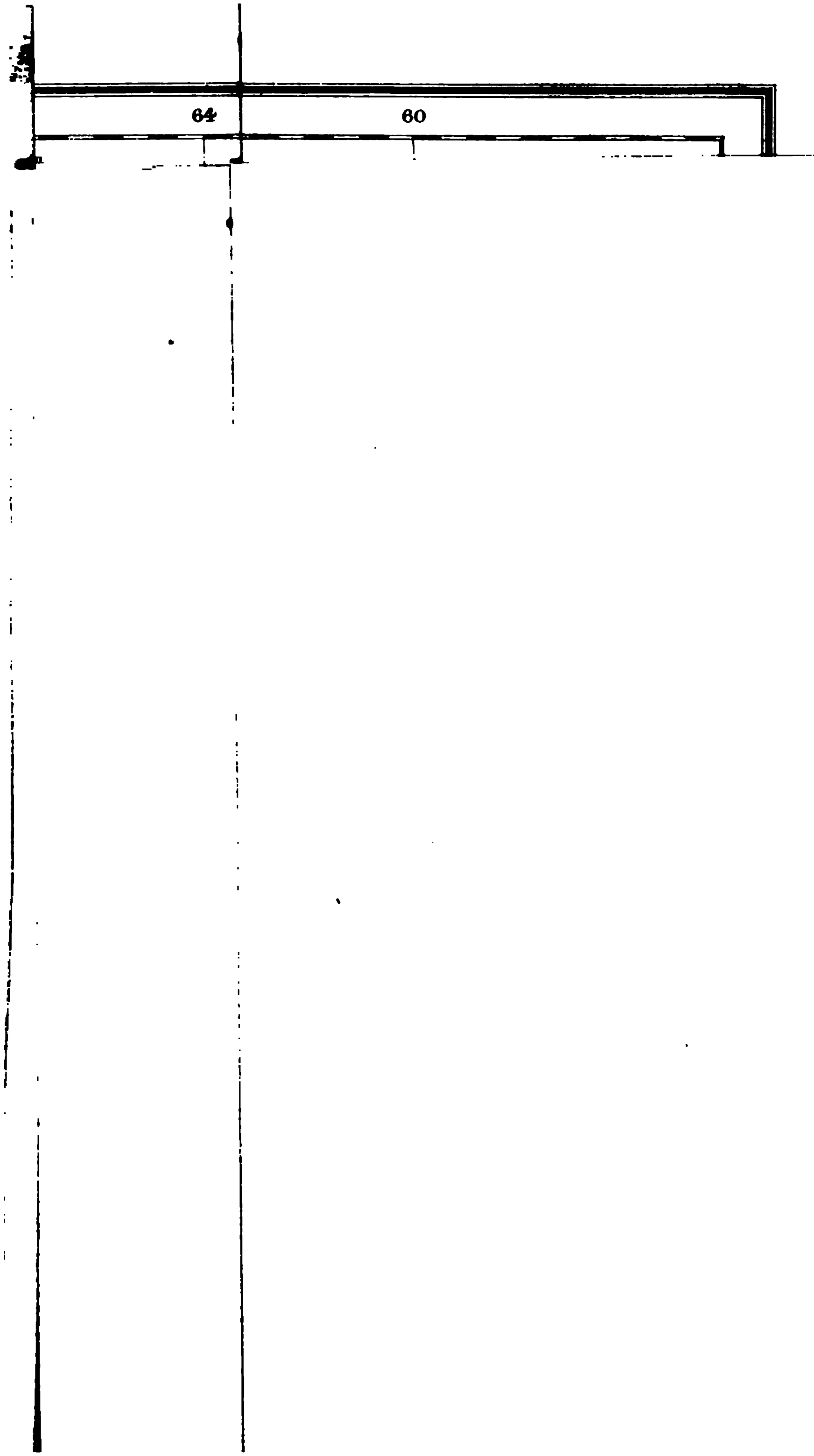
The dark-coloured dykes of igneous rock occurring in the Cobequids have usually been regarded as diorites; but two specimens, one from a dyke traversing the Upper Silurian beds at Wentworth, another from a dyke in the older Felsite series, which were kindly examined by Dr Harrington, proved to contain pyroxene instead of hornblende; and as they contain hydrous silicates as well, probably products of decomposition, would be included in the group now usually named Diabase. It is not improbable that other so-called diorites of the Cobequid series, in the county of Pictou and elsewhere, may be really of the nature of diabase. Some of the more coarsely crystalline igneous rocks occurring in this formation undoubtedly contain hornblende, and are true diorites and syenites. The term Felsite is used in this supplement for rocks composed chiefly of compact Orthoclase Feldspar, usually with excess of Silica and sometimes porphyritic. These rocks are usually termed "Compact Felspar" in Acadian Geology.

6. *New Brunswick Geology.*

Professor Bailey informs me that rocks similar in character to the Laurentian have been recognised in York County, in the interior of New Brunswick. He also mentions an additional outcrop of the Acadian group, flanking the Huronian rocks on their northern side, and constituting the fifth parallel belt of this formation now known in Southern New Brunswick. He also states that the Lower Carboniferous Albert shales are found to underlie unconformably the remainder of the Lower Carboniferous formation,—an effect, probably, of local crumpling and partial denudation in connexion with the changes which introduced the deposition of the coarse rocks which succeed these shales. The details of these discoveries will be found in Professor Bailey's and Mr Ells's forthcoming Reports to the Director of the Geological Survey of Canada.

REFERENCE TO PALÆONTOLOGY

In the Third Edition of "Acadian Geology."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